An evaluation of the ecological impacts of sand mining on the Mokolo River in Lephalale, South Africa

by

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Declaration

I **Maeko Mokgadi Precious** hereby declare that the dissertation, which I hereby submit for the degree of **Masters of Environmental Science** at the University of South Africa, is my own work and has not previously been submitted by me for a degree at this or any other institution. I declare that the dissertation does not contain any written work presented by other persons whether written, pictures, graphs or data or any other information without acknowledging the source.

I declare that where words from a written source have been used, the words have been paraphrased and referenced and where exact words from a source have been used, the words have been placed inside quotation marks and referenced. I declare that I have not copied and pasted any information from the Internet, without specifically acknowledging the source and have inserted appropriate references to these sources in the reference section of the dissertation. I declare that during my study I adhered to the Research Ethics Policy of the University of South Africa, received ethics approval for the duration of my study prior to the commencement of data gathering, and have not acted outside the approval conditions.

Student's signature

Date

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Abstract

This study aimed to evaluate the ecological impacts of sand mining on the Mokolo River, in Lephalale. The study focused on the water quality, macroinvertebrates and physical disturbances as indicators in order to determine the ecological impacts of sand mining on the Mokolo River. The water quality variables, which this study entailed, were related to sand mining and other sources of pollution such as coal mining, power station industries, agriculture and wastewater treatment works on the Mokolo River. The water quality results for pH, electrical conductivity (EC), total alkalinity (CaCO3), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), chloride (Cl), fluoride (F), sulphate (SO_4) and nitrate (NO_{3}-N) were not over the limits, however turbidity, total coliforms and *E. coli* were over the limits as per the Target Water Quality Guideline (TWQG). The River Health Programme (RHP) was done at upstream, sand mining and downstream areas in the Mokolo River using the South African Scoring System Version 5 (SASS5). The ecological status at the upstream and downstream areas changed from class C (March 2018) to class B (November 2018), indicating that the ecological status improved in those areas of the Mokolo River. However, at the sand mining area the ecological status has not improved and it was seriously modified due to the physical disturbance as a result of sand mining. Ecological impacts, such as the removal of marginal and riparian vegetation, erosion, disturbed riverbed, undercutting and collapse of riverbanks, loss of adjacent land, river deepened, river widened, water pools, in stream sand stockpiles and river diversions, were determined at the sand mining area. No physical disturbances at the upstream and downstream areas were determined. The findings of this study indicate that the ecological impacts of change in water quality at the upstream and downstream areas was due to high turbidity, Total coliforms and *E. coli.* The absence of sensitive macroinvertebrates and loss of macroinvertebrates and the physical disturbances within the Mokolo River was because of sand mining. The study indicates that sand mining has negative impacts on the water quality, water quantity, macroinvertebrates and physical characteristics of the Mokolo River.

Key words: Sand mining, water quality, ecological impacts and ecological status

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List of Symbols and Abbreviations

Abbreviation	Designation
Ca	Calcium
$CaCo_3$	Calcium carbonate (total alkalinity)
Cl	Chloride
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
DMR	Department of Mineral Resources
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
F	Fluoride
K	Potassium
LWMA	Limpopo Water Management Area
Mg	Magnesium
Na	Sodium
NAEHMP	National Aquatic Ecosystem Health Monitoring Programme
NCMP	National Chemical Monitoring Programme
NMMP	National Microbial Monitoring Programme
NO_3-N	Nitrate as Nitrogen
NWA	National Water Act
REMP	River Eco-Status Monitoring Programme
RHP	River Health Programme
SASS5	South African Scoring System version 5
SAWQG	South African Water Quality Guidelines
SO_4	Sulphate
SS	Suspended solids
TDS	Total dissolved solids
TWQG	Target Water Quality Guideline
UNISA	University of South Africa
WMA	Water Management Area
WULA	Water Use Licence Application

List of Definitions

Term	Definition
Baseflow	- the normal stream flow of a river as maintained by groundwater inflow
Calcrete	- an indurated layer cemented by calcium carbonate
Conglomerate	- a rock composed of rounded, water-worn pebbles, cemented in matrix of sand, silt, clay, calcium carbonate, silica, iron oxide or mixtures of these
Dolerite	- a dark, medium grained igneous rock, containing plagioclase, pyroxene and olivine
Ferricrete	- is a hard, erosion-resistant layer of sedimentary rock that is cemented into duricrust by iron oxides
Gravel mining	- mining of rounded or angular fragments of rock up to 3 in (2 mm to 7.6 cm) in diameter
Riparian	- pertaining to the banks of a river
Sand mining	- mining of individual rock or mineral fragments from 0.05 mm to 2.0 mm in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10% clay
Water pools	- a small body of still water
Water table	- the upper surface of the zone of saturation

CHAPTER 1
GENERAL INTRODUCTION AND THESIS OUTLINE

1.1 Introduction and background

Many years ago, sandy rivers have been attracting miners to extract sediments from those water resources, which led to over exploitation of the sediments (Rascher *et al*., 2018). Mining is economically important in South Africa as it contributes towards socio-economic development in the country. However, it should be acknowledged that the processes of mining such as prospecting, blasting, bulk sampling, extraction of ore, plant processing and transporting the produced product has the potential to degrade the natural environment (Rabie, in Ashraf *et al.* 2011). Negative impacts of mining arise from the type of mineral being mined, method used, equipment used, chemical used for their processes and sensitivity of the water resources and aquatic species and habitats (Jain *et al.*, 2016). Good water quality is essential for sustainable life and necessary for activities such as power station industries, agriculture, recreational and domestic use for beneficial use and economic development. Good water quality is also required for the ecosystem and human use for sustainability (Jain *et al.*, 2016). Poor water quality and reduced water quantity in a river can have a negative effect on activities such as mining, power station industries, agriculture, recreational, aquatic species, habitats, and human use, which are dependent on the health of the river for survival and development (Jain *et al.*, 2016).

Mining within a river causes negative impacts on aquatic life, water quality and quantity (Jain *et al.*, 2016). Sand mining causes negative impacts on the ecology of a river and the impacts are irreversible (Bindhusri and Arunachalam, 2015). Sand mining is a short to medium activity as it depends on demand and supply, and it is commonly used for manufacture of plaster, mortar and concretes; therefore any construction and developments of bridges, houses, mines, industries, roads and shopping malls requires sand, which increases demand (Ngcofe and Cole, 2014). Sand mining is regarded as important in developing countries such as South Africa because there is a need to provide infrastructure and housing for all citizens to ensure better living conditions for all. Sand mining has increased in most South African rivers and public concerns have risen due to the increased negative ecological impacts on the rivers (Smith and Collis, 1993; Romy, 2014). Despite these concerns, authorisations are granted to applicants who submit authorisation applications to relevant departments, such as Departments of Water and Sanitation (DWS), Mineral Resources (DMR) and Environmental Affairs (DEA) to continue with sand mining and there are also illegal sand miners (Romy, 2014).

Sand mining has potential negative impacts on the in-stream and riparian habitats (ecological characteristics which include the water quality and quantity and physical characteristics) of the river. The physico-chemical variables, which can be affected by sand mining in rivers, include pH, turbidity, suspended solids (SS), total dissolved solids (TDS) and electrical conductivity (EC). The riverbed, riverbanks and riparian vegetation are affected, as excavation of sand and clearing of vegetation occurs during sand mining (Bindhusri and Arunachalam, 2015). Disturbed habitat and changes in water quality in a river negatively influence the ecology (Bindhusri and Arunachalam, 2015).

The ecological status of a river can be determined by the analysis of macroinvertebrates present, change in water quality and physical disturbances. Apart from the sand mining in the Mokolo River, the ecology, which includes the water quality, biota (plants and animals), vegetation, and environment. might be affected by other activities/sources of pollution such as coal mining, coal power station industries, agriculture and wastewater treatment works that are within the catchment, which also contribute effluent discharges and atmospheric discharges into the Mokolo River. These activities can be associated with low pH, sulphates, fluorides, chlorides, potassium, sodium, nitrates, magnesium and alkalinity as carbonate or bicarbonate or hydroxide in water (Chapman and Kimstach, 1996). Effluent from wastewater treatment works and animal faeces can contribute to elevated levels of total coliforms and *Escherichia coli* (*E. coli*) in the Mokolo River. The living and non-living organisms interact with each other and the environment in which they live, therefore if there is a change in water quality and physical disturbances on the environment will negatively influence on the ecology of the river.

Mining in South Africa is regulated by national and provincial legislations. The DEA and DWS are the national regulators and their various provincial departments are responsible for environmental matters. The DMR is responsible for regulating mining as the custodian of the minerals in South Africa. All the departments are responsible for regulating the environment, granting authorisations, to ensure that there is minimum degradation, and mitigation measures are put in place to protect the environment (Romy, 2014). Due to poor regulation of sand mining activities, previous mining has left the environment eroded and degraded (Romy, 2014). Many sand mining activities in South Africa operate unlawfully which increases pressure on the legal sand miners due to more competition for sand mining and environmental compliance costs (Romy, 2014). Many sand mining activities in South Africa are small-scale mining which operates unlawfully within rivers in communities and they get permission to mine from traditional authorities and land owners (Amposah-dacosta and Mathada, 2017). The traditional authorities and land owners condone illegal sand mining in their areas of jurisdiction and disregard legislation (Amposah-dacosta and Mathada, 2017).

The aim of this study was to assess the potential negative impacts associated with sand mining on the ecology of the Mokolo River, which includes the water quality, macroinvertebrates and physical characteristics. The study will also assess the water quality variables that are associated with power station industries, wastewater treatment works, coal mining and agriculture activities that are within the catchment of the Mokolo River, in order to determine whether they have negative impacts on the ecology apart from sand mining. The study will also help decision makers, such as the DWS, the DEA and the DMR to consider ecological impacts resulting from the sand mining activities and make objective decisions when granting authorisations for sand mining.

1.2 Delineation of the scope of the study

The water quality data used in this study includes secondary and primary data. The secondary data water quality was collected between the periods of September 2013 to December 2016. The primary water quality data was collected between the periods of March 2018 to December 2018. The following water quality parameters pH, EC, total alkalinity ($CaCO_3$), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), chloride (Cl), fluoride (F), sulphate (SO_4) and nitrate (NO_3-N), turbidity, total coliforms and *E. coli* were part of the study and analyses was done by Capricorn Veterinary Laboratories. River health assessment was conducted at upstream, sand mining and downstream areas of Mokolo River using macroinvertebrates as biological indicators in March 2018 and November 2018. Physical observations of sand mining impacts on the Mokolo River were recorded and pictures were taken during the period of January 2018 to December 2018.

The study limitations were due to river health assessment only conducted in March 2018 and December 2018 because during the winter season the river was dry. The winter assessment provided a gap in terms of the research as it relied only on SASS5 results for March 2018 and December 2018. The water quality samples were also not collected during the winter period in 2018 as the river was dry. However, the data was still enough to make conclusion. All the physical observations of the impacts were recorded.

1.3 The statement of the problem

Sand mining within a river result in disturbed and collapsed riverbanks, erosion and change in water quality and degraded ecosystem (Barman *et al*., 2017). Sand mining as it occurs there is disturbance of a riverbed and result in the aquatic species and habitats to become vulnerable and negatively influenced (Barman *et al*., 2017). Sand mining causes change in water quality and quantity, and disturbed aquatic habitats and loss of aquatic species (Jain *et al.*, 2016). There is a loss of aquatic species as the sand is removed due to loss of nutrients contained in the sand for survival (Barman *et al*., 2017). During sand mining there is a loss of vegetation, change in sediment composition and loss of nutrients (Kaikkonen *et al*., 2018). River diversions are formed during sand mining, which result in change of water flow (Barman *et al*., 2017). The change in water quality and quantity negatively influences the water users, which depends on the river for access to clean water for domestic purposes (drinking, washing, farming, etc.) (Barman *et al*., 2017). Use of excavators and heavy machineries during sand mining deepens and widens the river; therefore, it increases water flows and flood during rainy seasons. The increase in water flow in a river result in erosion and collapsed riverbanks and high sedimentation load (Xijun *et al*., 2014). Sand mining causes high turbidity and suspended solids in a river and it reduces the amount of sunlight, which penetrates the water, which leads to loss and migration of the aquatic species (Barman *et al*., 2017).

Uncontrolled sand mining on the riverbed (Bindhusri and Arunachalam, 2015) causes the destruction of a river. The removal of sand in high quantities from the river, result in change of the morphology and result in change of sediment supply within the system (Rascher *et al*., 2018). Sand acts as a sponge and allows water flowing in the river to be absorbed and percolate and recharge the aquifers (Jain *et al.*, 2016). The surface water resources recharge the groundwater (aquifers), therefore if more sand is removed from the riverbed will result in increased or decreased flow and water pools, and high evaporation, which will result in reduced water quantity in the system, therefore less recharge to the groundwater (Jain *et al.*, 2016).

Increased sand mining led to change in sediment composition, water transparency and decrease of nutrients in a river, which resulted in loss of Biota (Meng *et al.,* 2018). The creation of river diversions and instream sand stockpiles reduces the flow of water in a river, which leads to water ponding and less water flow to downstream (Smith and Collis, 1993). The reduction of water in a river causes the water table to be lowered, as it can no longer be recharged from the surface water resource (Jain *et al.*, 2016). The groundwater yield is reduced because of land clearing near the river for sand stockpiling, which leads to the surface water run-off to increase and result in less infiltration of water into the soil (Jain *et al.*, 2016). The lowered water tables negatively affect the lives and livelihoods of the communities, which are dependent on the groundwater in the area, as they must drill deeper boreholes to access the water. Therefore, reduction of water quantity in the surface water resource negatively affects the groundwater water resource (Jain *et al.*, 2016).

Cost-benefit assessment of sand mining for eighteen Rivers in e-Thwekwini (Durban) conducted by Romy (2014) indicates that the rate at which sand is extracted exceed the natural replacement of sand in the system, which causes a high loss of sand and degrades the rivers. Sand mining activities are mostly operating illegally and few have permits (Romy, 2014). The illegal miners do not have authorisations to account for any environmental cost associated with their activities. Their activities in rivers included changes in morphology of the river, loss aquatic species, disturbed aquatic habitats and change in ecosystem food chains (Romy, 2014).

The change in water quality and quantity has negative influence on the aquatic species and habitats and human use (Jain *et al.*, 2016). The macroinvertebrates species cannot tolerate and survive in polluted water and disturbed habitats. In Ghana, sand mining in the oceans and dunes caused the ghost crabs to die and some migrated due to intolerant to the changed ecosystem (Jonah *et al*., 2015). According to the study by Musonge *et al.* (2019), the deterioration of water quality in rivers has negative impacts on the macroinvertebrates and result in loss of sensitive macroinvertebrates, which cannot tolerate pollution.

1.4 The rationale for this study

The National Development Plan (NDP) version for 2030 for government is envisaged to be phased in over three successive Medium Term Strategic Framework (MTSF). The NDP has different outcomes for government to implement. The relevant outcome for this study is outcome 10, which talks to protect and enhance our environmental assets and natural resources. South Africa faces challenges of deteriorating environmental quality because of pollution and degradation of natural resources. The national water resource strategy in terms of National Water Act (NWA) provides framework within which water should be managed in water management areas. The strategy provides framework for the protection, use, development, conservation, management and control of water resources within South Africa.

The DWS is responsible for regulating any activities, which might impact negatively on the water resources. The Department uses the NWA of 1998 (Act 36 of 1998) (Hill and Kleynhans, 1999), for the protection of water resources through water use authorisations (Hill and Kleynhans, 1999). When granting the authorisations, the process involves identifying the sensitivity of the water resource, ecological impacts, activity impacts, mitigation measures for the activity impacts and granting of the authorisation with conditions for monitoring and management to ensure that minimum impacts arise from the sand mining (Hill and Kleynhans, 1999). The DWS can also use Government Gazette Notice 704 for regulating mining activities to ensure protection of water resources.

A study by Brown *et al.* (1998) on the impacts of small stones and pebbles (gravel) mining in rivers at Arkansas, United States of America (USA) found that gravel mining causes changes of the river form, increases turbidity and has negative impacts on the macroinvertebrates. Brown *et al.* (1998) also found that when the river channel has been altered, widened, and lengthened and there was decrease in macroinvertebrates species in areas where the mining was taking place. Sand mining caused fish species to decrease in water pools, shallow and downstream areas of the rivers due to increased mining, which led to high turbidity in the water.

The study by Barman *et al.* (2017) in India found that physical characteristics shows erosion within the entire river as the result of high, water flow than the flow required for sediment transportation. Sand mining from riverbed changes the geomorphology and influences the flow parameters, and can alter the hydraulic condition of a river (Barman *et al.,* 2017).

Considering the ecological impacts likely to occur because of sand mining in the Mokolo River and the limited studies in this regard from the study area, this study will provide much needed insight into ecological impacts, which include the water quality, macroinvertebrates, and physical impacts of sand mining in the Mokolo River. The study will provide more insight on the associated impacts of sand mining in Rivers. This will benefit the authorities/regulators when granting authorisations or permits for sand mining. The authorities will be able to apply more stringent conditions to ensure that rivers are not degraded due to sand mining.

1.5 Research questions

The following questions will address the concerns related to sand mining in the Mokolo River:

i. Does the change in water quality due to sand mining have an impact on the ecology upstream and downstream of the Mokolo River?

ii. Does the sand mining have impacts on macroinvertebrates, vegetation, riverbed and banks upstream and downstream of the Mokolo River?
iii. What are ecological impacts of sand mining in the Mokolo River and environmental mitigation measures in place to minimise such impacts?

1.6 The aims and objectives

The aim of the study is to evaluate ecological impacts of sand mining on the Mokolo River using physico-chemical and microbial analyses, vegetation, riverbed, riverbanks and macroinvertebrates as indicators.

The objectives of the study are as follows:

i. To determine the ecological impacts of sand mining in the Mokolo River using water quality as an indicator, upstream and downstream of the sand mining area;
ii. To determine the ecological impacts of sand mining in the Mokolo River using macroinvertebrates, vegetation, riverbed and banks as indicators, upstream sand mining and downstream of the Mokolo River;
iii. Make output-dependent recommendations on mitigation measures about the potential ecological impacts of sand mining in the Mokolo River.

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CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Mining is important for potential production, employment, income distribution and economic development (Farahani and Bayazidi, 2018). The study by Aguilar-González *et al.* (2018) in San José, Costa Rica, indicated that mining results in loss of biodiversity, water pollution and reduced hydro geological connectivity. Sediments in the rivers provides significant role for the ecology, geomorphology and the water quality (Yang *et al.,* 2018). Sand mining is widely recognised for the importance of construction and building industry for economic development in the country. It is used in construction purposes for making concrete, cement, levelling of roads, building, bricks, sandpapers and glass (Mutiso, 2014). Sand has also played important role in the society in which it acts as a buffer for waves and storms by protecting the infrastructure and communities near the rivers and oceans. Sand is also used in tourism industries for fabricated beaches for tourist attraction (Saviour, 2012). Sand mining is becoming a serious environmental problem, which causes negative ecological impacts in the rivers (Saviour, 2012).

There is less environmental governance of mining which result in economic, social and environmental impacts (Aguilar-González *et al.,* 2018). Without proper management of mining, it increases negative impacts on the environment and water resources, which will result into long-term degradation (Mutiso, 2014). The study by Bishit and Gerber (2017) indicated that sand mining has resulted in more ecological conflicts than any other minerals as most are small-scale mining and illegal. The ecological conflicts occurred because local communities were not able to access the natural resources from the river for their livelihoods. The sand mining affected the water quantity and quality negatively.

The study by Yang *et al. (*2018) in Yangtze River indicated that human influences such as river diversions, construction of instream dams and sand mining reduced sediments deposition and caused erosion on the riverbed. The human influences reduced the water quantity and affected the water quality of the River. The study indicated that sediments in the Yangtze River reduced significantly at the mining activities area and downstream, which resulted in environmental, ecological and social impacts.

The study by Trop (2017), in Israel indicated that there was an increase in mining and dumping of marine sand in the shallow waters of the Mediterranean Sea which resulted in disturbed surface area of the sea. The study indicated that marine sand is a non-renewable resource and its used in the modern world for purposes such as building, industry, protection and restoration of the coastal areas, wetlands and at the beaches to restore the sand lost as result of erosion. The removal of marine sand result in alteration of the surface area of the sea and sediment composition. The removal of sand cause changes in the depth of the sea, hydrological conditions and disturbance of aquatic habitat and aquatic species.

The studies by Lawal (2011) and Kori and Mathada (2012) indicated that extraction of gravel in a river result in degradation of biological communities because when gravel is removed it changes the river channel by deepening and widening the river, which increases the flow. Gravel mining in a river causes removal of macroinvertebrates, riparian and marginal vegetation, and disturbance of the riverbanks which has negative impacts on the ecology of the system. During heavy rains the rivers flood, which result in deposition of gravel/sand that restores the river, however if the area is dry and hot with minimal rainfall, sand mining will degrade the ecosystem. Sand mining has the following ecological impacts: change in the water quality, river channel and reduced water volume to recharge the aquifer, removal of riparian and marginal vegetation, collapsing of riverbanks and erosion. Increased sand mining in a river will cause the riverbed to degrade in which the macroinvertebrates can no longer tolerate and survive in that ecosystem (Wohl and Carline, 1998). As sand mining progresses, it widens and deepens the river and increases the flow of water, collapses the riverbanks and erodes the river (Yen and Rohasliney, 2013).

The study by Calle *et al.* (2017) indicated that excessive gravel mining within ephemeral Mediterranean river in Spain resulted in high modification of the system. The increased removal of gravel over years resulted in degradation of the system and the gravel could not be deposited during the floods, as the sedimentation connection was lost. The bedrock of the river was completely removed leaving the river with old cemented gravels and bedrock limestone. The vegetation along and within the river was destroyed which had negative impacts on the aquatic species and habitats of the system. During the floods, the water flow fast and there is less percolation; therefore, the river remained dry, which resulted in more eroded systems, and riverbanks collapsed. The role of the floods is important for the river to re-deposit the sediments however if mining occurs continuously without the river to re-deposit the sand, it causes degradation to the system. The study in Spain indicated that continuous gravel mining within rivers without recovery resulted in degradation of the rivers (Calle *et al.,* 2017).

In the study by Bindhusri and Arunachalam (2015), the authors found in the assessment of five sand quarries from the middle to lower reaches of the Tamiarparani River, in India, that instream, floodplain and terrace mining heavily damaged the ecosystem and its functionality. Therefore, it affected the cleansing capacity of the river, lowered the groundwater level, and damaged the infrastructure next to the river and removal of riparian zone and the destruction of floodplains.

The study by Arróspide *et al.* (2018) in Chile in the Maipo River indicates that gravel mining has significantly changed the functioning of the river. The gravel mining resulted in physical and ecological impacts affecting habitats, water quality, water quantity, and sediment transportation. The study showed that the increase of gravel mining in the Maipo River caused the collapsing of the riverbanks and erosion. The gravel mining has progressed downstream of the river affecting the infrastructure in the vicinity as the width of the river is expanding and posing risks to the infrastructure within the Maipo River. The gravel mining has modified and degraded the Maipo River. The study indicated that the instream mining is the most detrimental activity in which the negative impacts including the physical, ecological, water quality and quantity impacts evolve over time and from ten to hundred years before restoration of a water resource occurs (Arróspide *et al.,* 2018).

According to the study by Pop *et al.* (2019), mining within the water resources causes changes in sediment composition. The study indicated that the sediments in natural and undisturbed water resources were of good particles size, however at the disturbed area the sediments were of poor particles size. Increased removal of sand from rivers causes environmental degradation of the rivers (Roth *et al.,* 1996). It poses risks to the bridge's crossings, riverbanks and other infrastructure close to the river because as the sand is removed, this causes instability of the riverbanks and high flow of water which will cause more erosion and damage to the structures within and along the river. Sand mining in the river lowers the surface area of the system and causes riverbanks to collapse and erode. Over extraction of sand in the rivers can lead to depletion of sand which causes the system to widen and deepen, and increases the river mouths and coastal inlets (Jonah *et al.*, 2015). The widening and increased mouth of the rivers may introduce the salty water from the nearest sea, which will have negative impacts on the ecosystem due to the change in water quality (Jonah *et al.,* 2015).

The study by Meng *et al.* (2018) in China Lake indicated that sand mining activities have led to serious environmental concerns. The impacts resulted from sand mining in the lake were an increase in water depth, turbidity and changes in sediment composition. The sand mining caused changes in water transparency, water quality, water quantity and reduced the level of nutrients in the lake. Where dredging was occurring, there was significance reduction in macroinvertebrates in the lake. During sand mining there was sediment fining which caused instability of the lakebed, which resulted in reduction of the organic nutrients. The increase in water depth and changes in water transparency affected distribution of macroinvertebrates in the lake. Sand mining negatively influenced the ecology of the China Lake (Meng *et al.* 2018).

Farahani and Bayazidi (2018) at Iran in the Tatao River found that sand mining activities were associated with negative environmental impacts such as loss of land, erosion and loss of biodiversity. During sand mining different pits in the river were formed which resulted in the water quantity to be reduced and formed water pools. Sand mining in the river resulted in long-term impacts such as, no flow of water and removal of riparian vegetation, collapsed riverbanks and loss of all the aquatic species. As the river dried up it affected the surrounding plants and wild animals, downstream users and its tributaries, as water was no longer flowing. The sand mining in the area had long-term environmental impacts, which will last over a longer period before restoration can take place in the River.

Degradation of the river due to sand mining causes aquatic weeds and alien invasive species to invade and infest the river, which increases competition for food and survival. The infestation of the alien species and aquatic weeds in the river consumes a lot of water, which will reduce the flow in the river (Lawal, 2011). The sand stockpiles near the riverbanks increases sedimentation and damming of water in the river. The river system has its original functionality before disturbance; therefore, sand mining disrupts the ecological functions of the natural ecosystems (Kori and Mathada, 2012).

The demand for sand increases as the country is developing, and sand mining has negative environmental impacts, therefore the miners and regulators should coordinate to ensure that sand mining happens in a sustainable manner for water resource protection (Kori and Mathada, 2012). Negative impacts such as erosion, unstable river slopes, change in water flow and depth occurs due to poor regulation of sand mining by authorities (Wang *et al.,* 2012). The study indicated that without proper regulation, the sand miners will over mine the water resources which will impact negatively on the ecosystem. Therefore, proper planning and design before mining is essential to ensure that the negative impacts on the water resource are minimised (Wang *et al.,* 2012).

2.2 The interconnection of groundwater and surface water in the Mokolo River

The Mokolo River used to flow throughout the year many years ago, however as there is high abstraction, sand mining and instream dams, resulted in reduced water quantity in the river. Reduced water quantity in a river negatively affects the groundwater of the Mokolo River. Therefore, ecological impacts, which will arise from this study, will have a negative effect on the groundwater, as there is connection of the surface water and groundwater in the Mokolo River. According to Jain *et al.* (2016), there is interconnection between the surface water and groundwater. Mining that occurs within the rivers result in long-term environmental impacts such as lowered water tables and reduction of water recharge into the aquifers, change in water quality, reduced water quantity and change in land formation. Environmental impacts on the surface water resources negatively influence the groundwater (Jain *et al.,* 2016).

According to Seaman *et al*. (2013) the Mokolo River and its tributaries, were classified as perennial over 60 years ago, however; the status has changed, as the rivers do not flow during dry seasons. In terms of the National Water Act (NWA) (Act 36 of 1998) (Seaman *et al.*, 2013), the Dept. of Water and Sanitation (DWS) need to determine Intermediate Reserve or Reserve for water resources. The Reserve must be determined for quaternary drainage in a catchment in order to determine the water quality, quantity and reliability of water (Seaman *et al.*, 2013). The Reserve is done to ensure that the water can sustain human use and aquatic ecosystem and that it meets the requirements for economic development without influencing negatively on the long-term integrity of the ecosystems (Seaman *et al.*, 2013). The Intermediate Reserve was determined for five sampled sites within the Mokolo River and the results revealed that the system has changed from naturally perennial to non-perennial (Seaman *et al*., 2013). The surface and baseflow has decreased due to irrigation, mines and power station activities upstream and downstream of the Mokolo Dam, which have negatively influenced the ecology of the Mokolo River (DWAF, 2008a).

Groundwater that flows towards the river passes through faults and dykes, which impedes the flows to the river; however, it enhances the flow parallel to planar features through permeable zones. Groundwater is recharged during the rainy seasons where the groundwater levels are too high, allows the water to discharge into the Mokolo River and the tributaries, thus when there will be enough flow in the river (DWA, 2010). If the water levels are high in the river compared to the underlying groundwater levels due to high rainfall the flow in the river will automatically recharge the groundwater (DWA, 2010). During dry seasons, surface water can no longer recharge the groundwater and the levels decreases in the aquifer. Therefore, the surface water in the Mokolo River is interconnected with the groundwater (DWA, 2010).

Sand mining causes change in water quality and contaminate the groundwater due to the interaction of surface water and groundwater in the Mokolo River (DWA, 2010). Any sources of pollution that might arise in the river will influence the groundwater. During sand mining, there are sand stockpiles disposed within the Mokolo River, which prevents the water to flow downstream thus, affecting the ecology, water users and recharge of the groundwater. The ecological impacts including change in water quality, river channel and removal of riparian vegetation, collapsing of riverbanks and erosion will have negative impacts on both the surface water and the groundwater in the Mokolo River as there is interrelation (DWA, 2010).

2.3 Methods of sand mining

There are various mining methods used for hard rock extraction in quarries, which are also applicable to sand mining. There are three types of sand mining, namely dry-pit, wet-pit mining within an active river and bar skimming or "scalping" (Hill and Kleynhans, 1999).

2.3.1 Dry-pit mining

Dry-pit sand mining occurs in dry rivers, which never flow, quarries and from the surface of land where there is accumulation of sand. The dry-pit sand mining process involves the use of excavators, scrapers, bulldozers and heavy trucks to remove and transport the sand. The area to be mined will be cleared using scrapers to remove vegetation then sand is excavated, stockpiled, and processed in the screening plant to produce certain quality of sand required by the different industries for construction purposes. The ecological impacts that will arise from dry pit mining include loss of vegetation, disturbed riverbed, loss of wildlife and aquatic habitats, which will disrupt the ecological cycle in that river (Hill and Kleynhans, 1999).

2.3.2 Wet-pit mining

Wet-pit sand mining occurs in perennial and non-perennial rivers or drainage channels in where there is flow throughout the year whilst the other flows during rainy seasons. The wet-pit sand mining process involves the use of scrapers, dragline, hydraulic excavators and heavy trucks for removal and transportation of sand. The area to be mined is cleared using scrapers to remove riparian and in-stream vegetation and its riverbanks and stockpiling area (Hill and Kleynhans, 1999). During sand mining there is dewatering in the rivers for site accessibility, the sand is stockpiled to dry. The dried sand is processed in the plant to produce certain quality of sand product needed by different industries for construction purposes. Wet mining process causes ecological impacts such as high sedimentation in the river, reduced water quantity, change in water quality, collapsed river-banks, and changes in river channel, disturbed riverbed, and loss of riparian vegetation, loss of habitat, loss of aquatic species and erosion which impacts negatively on the ecosystem (Jain *et al.*, 2016).

2.3.3 Bar skimming

Bar skimming or scalping of sand mining occurs within the rivers below the water tables. Bar skimming of sand involves the use of scrapers, dragline or hydraulic excavators and heavy trucks for transportation. It involves the process of removal of vegetation and excavating the riverbeds and stockpiling then processed in the plant to produce certain quality of sand product needed by different industries for construction purposes. Bar skimming involves completely removal of vegetation, sand and pumping of water in the river which causes change in water quality, loss in macroinvertebrates, loss in vegetation and negatively impacts the ecosystem as all the living (e.g. fish and worms) and non-living (e.g. rocks) organisms in that system can longer survive (Hill and Kleynhans, 1999).

2.4 Impacts of sand mining in the river on the ecology (habitats, biota, water quality, water quantity and physical impacts)

Sand mining over a long period degrades the water resources. The mining, which occurred many years ago in Apalachicola River, according to the study by Mossa *et al.* (2017), has left the river with changed morphology and sediment composition. There was removal of vegetation, river diversion, loss of adjacent land, erosion, change in water flow and disturbed floodplains. The study indicated that after many years of mining the river has not been restored, therefore restoration plan is required to ensure the sustainability of the river.

Sand mining in the river has negative influence on the ecology, which includes the physical disturbance, erosion, loss aquatic species, disturbed aquatic habitats, and change in water quantity and water quality. Other negative influence includes degradation of riverbed, and change in geomorphology, stability, depth, and width. Sand mining and stockpiles of sand in the river increases turbidity and suspended solids, which result in change in water quality and creation of water pools and reducing the water flow (DWAF, 1996). Altering the ecosystem characteristics has negative impacts on biota and habitats (DWAF, 1996).

According to the study by Forio *et al*. (2017) indicates that the sand mining within a water resource disturbs the aquatic habitat, which results in loss of aquatic species. During sand mining, there was disturbance of the aquatic habitat, change in water quality and quantity, which led to loss of macroinvertebrates in the system (Forio *et al.,* 2017). Sand mining activities result in physical impacts, which involve clearing of instream vegetation, removal of riparian vegetation, sand stockpiles within the river and collapsed riverbanks (Smith and Collis, 1993). These cause ecological impacts such as degraded riparian zones, collapsed and destabilised riverbanks, erosion at the sand mining and downstream areas of the river, alteration and degradation of the riverbed, and change in river form and change in water flow (Smith and Collis, 1993). The aquatic species and habitats are disturbed during sand mining and there is reduction in production and feeding opportunities as the aquatic ecosystem has been disturbed and changed (Smith and Collis, 1993).

Instream sand mining in Nigeria resulted in the removal of vegetation, changes in aquatic ecosystem and changes in soil profile on the surface and subsurface of the river, which resulted in decreased macroinvertebrates populations (Lawal, 2011). Sand mining in the rivers causes destruction of the riverbed, lowers the water table, and erode the riverbanks, deteriorates the water quality and degrades the ecosystem. The study indicated that increased sand mining causes destruction and degradation of Rivers (Lawal, 2011).

Ecological impacts on biota resulting from bedrock material mining were caused by alteration of the flow patterns, modification of the riverbed caused by machineries used when excavating, this damages the riverbed and influences the biota and habitats (Smith and Collis, 1993). The alteration of the riverbed will cause the macroinvertebrates and aquatic habitats to be negatively impacted, as some aquatic species cannot tolerate and survive in degraded aquatic habitats (Smith and Collis, 1993). As the machineries excavate the sand from the river, there are suspended sediments, which cause high turbidity, and total dissolved solids in the water that will lead to migration and loss of some aquatic species in the river (Smith and Collis, 1993).

Sand mining damages the riparian and marginal vegetation and instream habitats as result of excavation by machineries, which remove the vegetation along the riverbanks and on the riverbed, which result in habitat change and then the biota can no longer survive in such water (Smith and Collis, 1993). During sand mining, there are excavators and heavy trucks used as part of mining operations in the river and haulage of sand, which affects the water quality, quantity and degrades the ecosystem. Surface water from the rivers recharge the groundwater therefore any polluted water due to sand mining or other activities will influence the water quality and water quantity of the aquifers (Bekri and Yannopoulos, 2012).

According Ashraf *et al*. (2011) instream mining can have costly effects for mitigation, rehabilitation and management of impacts of sand mining in the river. Mining operations starts with construction which involves clearing of vegetation within the riverbanks, in land vegetation and stockpiling of sand on the cleared land, which result in the loss of land that can be used for agricultural purpose and loss of habitats for species in the area. A complete clearing of vegetation reduces the faunal population in the mining area. Any sudden increase or decrease of sediments supply in the river, which is not caused naturally, will cause the riverbed and riverbanks to destabilize. The affected water quality and habitats influence negatively on the aquatic species in the river (Newell *et al*., 1999).

Sand mining causes change in water quality and water quantity in the rivers, which result in the system to change from its original functionality. The macroinvertebrates and other downstream water users cannot tolerate any changes in the ecosystem, which rely on the river water for beneficial use. All aquatic species in a certain ecosystem require specific habitat conditions to ensure that there is long-term survival without any degradation (Ashraf *et al*., 2011).

Sand mining causes high sedimentation in the river, which lead to increased turbidity, total dissolved solids (TDS) and suspended solids (SS) at the mining area and downstream of the mining area, which has negative influence on the ecosystem. The change in water quality will have a negative impact on the macroinvertebrates, riparian vegetation, aquatic habitats and aquatic species in the system, as they require water that is not polluted and disturbed in order to thrive and survive; therefore, the ecology will be impacted if there is pollution and physical disturbance in the river (Smith and Collis, 1993).

The study by Mossa *et al.* (2017) in Apalachicola River in the United States of America (USA) indicated that sand mining and disposal of sand near the river has influenced negatively on the water quality, changed the morphology and widened the river. The disposal of sand near the river increased over years and formed hills. During rainy seasons, the sand from the hills erodes back into the river increasing sediments loads and restricting the flow of water to downstream water users. The study indicated that sand mining negatively influenced the water quality, water quantity, morphology and vegetation of the Apalachicola River. In France, Kerbiriou *et al.* (2018) indicated that sand and gravel mining from pits resulted in degradation of the aquatic habitats and aquatic species. The topography and the original functionality of the ecosystem have been changed, due to the gravel mining. The study indicated that in the areas, which have been mined out, the aquatic species and riparian vegetation started re-establishing ten years after the rehabilitation.

The study by Jain *et al.* (2016), found that during mining activities there is land clearing, river diversions and instream dams, which causes change in run-off patterns, percolation rates to groundwater, result in increased water flow for some areas, and decreased flow in other areas of the river. The aquatic species are sensitive to changes in flow and requires specific flow conditions. The change in flow in the river reduces sediments nutrients, aquatic habitat and species, and causes erosion of the riverbed and riverbanks. The increase in turbidity and suspended solids reduces the light penetration, causes changes in water temperature and an increase in biological oxygen demand and depletes oxygen. The physical impacts and chemical impacts negatively affect the ecology by reducing primary productivity, fish growth, and macroinvertebrates communities and damage the instream habitat and riparian vegetation.

Forio *et al.* (2017) in Belgium, indicated that in rivers of a multifunctional tropical island the sediment in the rivers provide a significant role for the macroinvertebrates. The sediments in the river serve as a habitat for some benthic macroinvertebrates and provide food for macroinvertebrates. The study indicated that mining of sand and gravel in the rivers reduces the level of water, creates pools within the rivers, which collects sediments and limit transportation of the sediments throughout the rivers. Sand mining also removes surface land vegetation, riparian and marginal vegetation and also causes erosion and collapse of riverbanks. The erosion affects the water quality of the rivers and as a result, reduces the abundance of macroinvertebrates. The study also indicated that the cumulative impacts of human activities near/pollution sources to the rivers such as agriculture, mining and industries impacts have negative influence on macroinvertebrate communities. Sand/gravel mining and other pollution sources in rivers of a multifunctional tropical island in Belgium negatively influenced the macroinvertebrates and water quality.

According to Lenat (1984), the number of macroinvertebrates present in ecosystem is the indicator of the water quality of the river. The polluted water causes reduction in abundance macroinvertebrates. According to Shan *et al.* (2016) in Hai River Basin at China, the number of taxa reduced due to historic mining in the river and other activities such as human access and disturbances, livestock access and point source pollution. The macroinvertebrates taxa in the river such as *Insecta, Crustacea, Gastropoda* and *Oligochaeta,* with 39 families and 95 genera has been identified. *Lymnaeidae* family and *Chironomus* genus*, Limnodrilus* genus, *Glyptotendipes* genus and *Tubifex* genus, have been found in the Hai River. The length of the river was widened and deepened, and there was less biodiversity. The ecosystem was found to be highly degraded as result of the human induced activities such as mining. The study indicated that most sites studied in Hai River were found to be poor with degraded ecological status.

2.5 Sand mining management in South Africa

Sand mining in South Africa is regulated by the Department Environmental Affairs (DEA), the DWS and the Department of Mineral Resources (DMR) to ensure that the environment is not degraded and the authorisations are in place to manage the negative impacts arising from the activities. The National Development Plan (NDP) version for 2030 for government is envisaged to be phased in over three successive Medium Term Strategic Framework (MTSF). The NDP has different outcomes for government to implement. The relevant outcome for this study is outcome 10, which talks to protect and enhance our environmental assets and natural resources. South Africa faces challenges of deteriorating environmental quality because of pollution and degradation of natural resources. The national water resource strategy in terms of NWA provides framework within which water should be managed in water management areas. The strategy provides framework for the protection, use, development, conservation, management and control of water resources within South Africa.

The DWS is responsible for regulating any activities, which might impact negatively on the water resources. The Department uses the NWA of 1998 (Act 36 of 1998) (Hill and Kleynhans, 1999), for the protection of water resources through water use authorisations (Hill and Kleynhans, 1999). When granting the authorisations, the process involves identifying the sensitivity of the water resource, ecological impacts, activity impacts, mitigation measures for the activity impacts and granting of the authorisation with conditions for monitoring and management to ensure that minimum impacts arise from the sand mining (Hill and Kleynhans, 1999). The DWS has also developed Government Gazette Notice 704 for regulating mining activities to ensure protection of water resources. The GN 704 has requirements under regulation 10 for mining sand and alluvial minerals from the watercourse and estuaries and also details measures which should be in place during mining operation in order to protect the rivers or estuaries.

2.5.1 Considerations and conditions when authorising sand mining operations

The requirements for regulating water uses are set out in terms Chapter 4 of the National Water Act of 1998 (Act 36 of 1998) (Hill and Kleynhans, 1999). The water user can only use water if the water uses are permissible under four categories in terms of NWA namely:

- permissible under Schedule 1 - a person may use water under Schedule 1 if the water will be used for reasonable domestic purposes;
- permissible as continuation of an existing lawful water use - it is a water use that has taken place at any time during a period of two years immediately before commencement of the NWA;
- permissible in terms of general authorisation - a general authorisation is Gazetted for a person to use water, however it may be restricted to specific water resource and geographical areas;
- permissible in terms of licence - water uses may be authorised under section 21 of NWA.

The water uses in terms of National Water Act of 1998 (Act 36 of 1998) (Hill and Kleynhans, 1999) of Section 21 includes:

- taking water from the water resource (a),
- storing of the water (b),
- stream flow reduction activities (d),
- controlled activities (e),
- discharge of waste or wastewater (f),
- disposal of waste or wastewater (g),
- removing water found underground (j),
- recreational use (k).

The water uses relevant to sand mining activities, is Section 21 (c) and (i): impending or diverting the flow in a watercourse or altering the bed, banks, course or characteristics of watercourse (Hill and Kleynhans, 1999). All water uses activities must be applied for and licensed unless it is listed in schedule I or is an existing lawful use or is permissible under a general authorisation, or if a responsible authority waives the need for a license (Hill and Kleynhans, 1999).

The authorisations are granted with standard conditions for sand mining or gravel extraction operation, which include the following conditions (Hill and Kleynhans, 1999):

- construction;
- monitoring;
- management and;
- rehabilitation.

The aim of the conditions is to restore the biotic integrity of riverine ecosystem, not just to repair the damaged abiotic components (Hill and Kleynhans, 1999). The standard conditions do not address all the negative impacts for a specific river, as there are not site-specific, however are standard conditions to all water resources. Therefore, this study will identify the ecological impacts in the Mokolo River and the sand miner's water use authorisation application for the river, will be given site-specific conditions in their granted authorisation related to the findings in this study.

2.6 Water monitoring programmes

2.6.1 Water quality monitoring

Water quality monitoring refers to the physical, chemical and biological characteristics of water (Diersing, 2009) and the measurement of the quality of water against the requirements or standards of the biotic species, human need or for other intended purposes (Johnson, 1997). The Water Resource Management has evolved over years to ensure that water users have water that is fit for intend use (Hohls *et al.*, 2002). The surface water quality in the rivers can be affected by activities such wastewater treatment works, industries, agriculture and sand mining or other mining activities (e.g. coal mines). Therefore, the DWS developed programmes to monitor the water quality such as National Chemical Monitoring Programme (NCMP) (Hohls *et al.*, 2002) and National Microbial Monitoring Programme (NMMP) (DWAF, 2002).

The NCMP (Hohls *et al.*, 2002) was established in the 1970s to assess the water quality of all the water resources in South Africa. The water samples were collected and analysed for constituents such as pH, electrical conductivity (EC) and inorganic ions (Hohls *et al.*, 2002). The programme was extended to include constituents associated with mining (coal and sand), agriculture, industries and wastewater treatment works activities. The NCMP aims to provide data and information on the surface inorganic and organic chemical water quality of South Africa's water resources (Hohls *et al.*, 2002). The constituents analysed for the Mokolo River includes pH, electrical conductivity, turbidity, total alkalinity as calcium carbonate, calcium, magnesium, potassium, sodium, chloride, fluoride, nitrate and sulphates to assess whether the water quality is impacted.

The goal of the NMMP (DWAF, 2002) is to provide data and information needed to assess and manage faecal pollution on a national scale for all water resources in South Africa. The constituents analysed for the Mokolo River in terms of microbial are *Escherichia coli* (*E. coli*) *and* total coliforms to assess whether there is faecal pollution in the system, which will impact negatively on the ecosystem.

2.6.2 River Health Programme (RHP)

The River Health Programme (RHP) (Chutter, 1998) is a national bio monitoring programme that collects, collates and distributes information on the overall ecological status (or healthiness) of the ecosystems of rivers in South Africa. The river health assessment should be done bi-annually (winter and summer seasons) as per the requirements of South African Scoring System Version 5 (SASS5) to determine if there are ecological changes in the rivers (Dickens and Graham, 2002).

The DWS initiated the process of developing the RHP in 1994. In 2016, the DWS replaced RHP to River Eco-Status Monitoring Programme (REMP). The National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) was developed to measure, assess and report on the ecological state of aquatic ecosystems (DWAF, 2008b). It detects and reports on spatial and temporal trends in the ecological state of aquatic ecosystems and identifies and report on emerging problems regarding the ecological state of aquatic ecosystems in South Africa (DWAF, 2008b). The REMP is a component of the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP). The RHP makes use of instream and riparian biological communities (e.g. fish, invertebrates, vegetation) to characterise the response of the aquatic environment to multiple disturbances (e.g. anthropogenic activities, sedimentation, erosion, etc.) (Kleynhans and Louw, 2007). The RHP reports on different aquatic indices and SASS5 is one of the indices which is part of this study (Dickens and Graham, 2002). The other aquatic indices which are not part of this study are Fish Assemblage Integrity Index (FAII), Riparian Vegetation Index (RVI) and Index of Habitat Integrity (IHI) (Dickens and Graham, 2002).

The SASS5 was developed for the purposes of assessing the ecological status of rivers and the standard was accepted as a method for rapid assessment for river water quality in South Africa using aquatic macroinvertebrates, accredited to ISO 18025 (Dickens and Graham, 2002). The SASS5 method operates on the principle that some macro-invertebrates are more sensitive than others, therefore if an abundance of pollutant tolerable species are found, but no sensitive taxa, it would be an indication that the water is polluted (Dickens & Graham, 2002). River health assessment should be done in flowing rivers. Water that has ponded, or pools in the river, cannot be assessed, as it does not give true reflection of the ecological status of the river (Dickens and Graham, 2002).

Macroinvertebrates require aquatic habitats, which are not polluted and degraded to ensure their survival (Shan *et al.,* 2016). The main purpose of the programme is to serve as a source of information regarding the overall ecological status of the Mokolo River. The RHP uses instream and riparian biological communities (e.g. fish, invertebrates, vegetation) to characterise the response of the aquatic environment to disturbances of mining (sand, coal, etc.), industries, wastewater treatment works and agriculture activities, therefore the integrity and health of biota in the river will be determined through the RHP.

2.7 Ecological monitoring variables (water quality, macroinvertebrates, vegetation and physical disturbances)

The water quality variables monitored as detailed below, are not all associated with the sand mining. However, there are related with other activities within the catchment such as coal mining, industries, agriculture and wastewater treatment works. Therefore, the ecological impacts of the Mokolo River will be determined by the analysis of macroinvertebrates present, vegetation, change in water quality and physical disturbances.

2.7.1 pH

The pH in water is factor of determining its corrosiveness. The normal pH ranges from 6-8.5 values according South African Water Quality Guidelines (SAWQG). The geology and the minerals found in a river or in the vicinity can affect the pH. The variation of the pH is affected by the bedrock and composition through which it moves, for example limestone or granite bedrocks. The acidic rain can also contribute to changes in pH of surface water (Barnard *et al.,* 2013). The pH is associated with activities such as mining (coal, gold), industries, and biological and anthropogenic, which discharges waste or wastewater into the river and which might increase or decrease the value of pH. The water is acidic as the pH decreases from neutral and basic as it increases from neutral. Sand mining in the river can influence pH, if the geology has bedrocks or soil composition that can cause variation in pH. The change in pH of water influences the taste of water, corrosiveness, solubility and speciation of metal ions (DWAF, 1996).

2.7.2 Turbidity

Turbidity is the reduction in transparency of water due to presence of suspended solids in a river. Turbidity is measured in nephelometric units (NTU). It usually consists of organic matter and inorganic matter (Barnard *et al.,* 2013). Turbidity can change in water seasonally according to the biological activities and surface water run-off (Chapman and Kimstach, 1996). Heavy rains and floods increase sedimentation in the river, which result in high turbidity (Chapman and Kimstach, 1996). As the sand is excavated from the river, the suspended solids increase and lead to high turbidity. Turbidity can also be caused naturally in a river, as it is eroded during floods through the transportation of sediments. High turbidity in water can cause growth deficiencies, mortalities, reduction in abundance of macroinvertebrates and reduces the amount of sunlight that penetrates the river, which will influence negatively the ecology (DWAF, 1996). The ecology of a river consists of living and non-living organisms, which interact with each other and the environment. Therefore, high turbidity in the river reduces the water clarity which leads to reduced amount sunlight into the water and causes the living and non-living organisms to die off as photosynthesis and productivity cannot take place (DWAF, 1996).

2.7.3 Electrical Conductivity (EC)

Conductivity is the measure of the ability of water to conduct electrical current. The water that conducts electrical current contains mineral salts (Chapman and Kimstach, 1996). Conductivity is measured in millisiemens per meter (mS/m), and it increases in water when the levels of salts are present. The salts that leach from the farming, wastewater treatment works, mining and industrial areas and the run-off is captured into the river (DWAF, 1996). The pollution source such as effluent discharges or surface water run-offs into a river can be determined by measuring the conductivity of the water (Chapman and Kimstach, 1996).

Sand mining increases the suspended solids or soil particles in the water in which the particles conduct electricity, therefore, the higher the suspended solids in water the high electrical conductivity, which will adversely affect the ecology of the river. Salts and inorganic chemicals in water, breaks into tiny electrical charged particles, which increase the ability of water to conduct electricity. Common ions in water that conduct electrical current includes sodium, chloride, calcium, and magnesium (Fondriest Staff, 2010).

2.7.4 Chloride (Cl)

Chloride in water can be caused by weathering of sedimentary rocks, effluents from industries, sewage and agricultural areas (Chapman and Kimstach, 1996). During winter periods there is salting of roads, which the surface water run-off from those areas will influence the chloride in the rivers (Chapman and Kimstach, 1996).

Sand mining does not have an effect on chloride, however if there are sedimentary rocks in the river and are disturbed, will result in increase of chloride in a river; however, activities such as discharge of wastewater from farming, wastewater treatment works, mining and industrial areas can cause chloride to increase in water. Chloride is the anion element of chlorine, which does not occur in nature measured as milligrams per litre (mg/l), however found as chlorine only. Water that has elevated chloride causes metals, structures and equipment to corrode (DWAF, 1996). High chloride in water can also cause water to have an undesirable taste, and be unfit for human and livestock consumption (Chapman and Kimstach, 1996).

2.7.5 Potassium (K)

Potassium in rivers is naturally found in low concentrations because it originates from rocks resistant to weathering. However, water from industries and agricultural activities contain potassium salts which can change the potassium concentrations in the river (Chapman and Kimstach, 1996). Sand mining in a river does not elevate potassium however, storm water run-off from agricultural activities, which contains fertilisers and domestic landfills, increases potassium in the water. Wastewater discharged into a river from the industries and mining activities can elevate potassium in a river (DWAF, 1996).

Potassium is measured in milligrams per litre (mg/l). Potassium causes water to have a bitter taste at high concentrations (DWAF, 1996). Water that contains elevated levels of potassium salts may kill the vegetation and macroinvertebrates in the river. High Potassium in water is not toxic however, potassium compounds such as potassium chloride in drinking water may interfere with nerve impulses, which interrupts all the body functions and affects the heart (Lenntech, [n.d.]c).

2.7.6 Sodium (Na)

Sand mining does not contribute to elevated sodium in the river however, if the riverbed contains sodium chloride naturally, then the water will contain concentrations of the sodium. Sodium is measured in milligrams per litre (mg/l) and usually occurs as sodium chloride in the environment and sometimes as sodium sulphate, bicarbonate or nitrate. Sodium is found as solid sodium chloride (rock salt) in geological deposits areas and when the area is disturbed the water will have high concentrations of sodium (DWAF, 1996).

Sodium levels in rivers are low in areas of high rainfall and high in arid areas with low mean annual precipitation. The sodium in water is not soluble and does not precipitate unless there is saturation. Industrial processes, which produce brine waste, contain elevated concentrations of sodium. Domestic wastewater also contains high levels of sodium. The run-off from irrigated farmlands into the river also contains high concentrations of sodium (DWAF, 1996).

2.7.7 Sulphate (SO_4)

Sand mining does not contribute to sulphates in a river. Sulphate is measured as milligrams per litre (mg/l) and is a common constituent in processed industrial water, which is produced from soils and rocks that contains sulphates mineral. Sulphates are soluble in water and tend to accumulate and increase concentrations. Sulphates are normally discharged from acid mine waste and the industries that use sulphuric acid or sulphates in their process. Ion exchange can remove or add sulphate to water and microbiological reduction or oxidation can interconvert sulphide and sulphate (DWAF, 1996). The microbiological process is slow and requires anaerobic conditions usually found in soils and sediments (DWAF, 1996). Power stations can also contribute to sulphate concentrations in a river. The combustion of fossil fuels results in atmospheric sulphur dioxide, which can release acid rain back into the system (DWAF, 1996).

2.7.8 Magnesium (Mg)

Magnesium is measured as in milligrams per litre (mg/l) and it occurs naturally from rocks in water however can also be derived from cattle feeds and fertilizers (Lenntech, [n.d.]b). Magnesium can be derived from weathering of rocks such as ferro-magnesium and carbonates rocks (Chapman and Kimstach, 1996). Sand mining does not contribute to elevated magnesium levels, unless the riverbed contains rocks, which naturally have magnesium therefore during excavation there will be high concentrations in the water. Magnesium causes water to have a bitter taste at high concentrations, which may lead to vomiting and diarrhoea (DWAF, 1996).

2.7.9 Calcium (Ca)

Calcium is measured in milligrams per litre (mg/l) and occurs naturally in water. Calcium can dissolve from limestone, marble, calcite, fluorite and apatite. The construction materials such as cement, concrete and brick lime contain calcium. Sand mining does not contribute to elevated calcium levels, however if there are limestones or any materials that contains the constituent in the river and during sand excavation is disturbed, it will result in high concentrations of calcium in water. Calcium is a determinant of water hardness, which may be toxic to the aquatic organisms, however calcium is good for some fish species in water and human consumption in water can only be limited to 32 mg/l (Lenntech, [n.d.]a).

2.7.10 Fluoride (F)

Sand mining does not contribute to elevated fluoride levels however less concentrations of it, is found in the river naturally from the rocks. Fluoride is measured in milligrams per litre (mg/l) and it occurs as fluoride ion or in combination with calcium, phosphates and potassium (DWAF, 1996). Fluoride occurs in sedimentary and igneous rocks in which low concentrations are found in aquatic ecosystems and higher concentrations are found in underground water. Fluoride can also emanate from industries discharges into the river. When fluoride reacts with phosphate ions and calcium forms a layer that settles out of the water column, which is not soluble. Fluoride in water is also aggravated by high temperature, therefore the high the temperature the more the toxic fluoride in water. The water with increased hardness reduces the toxic effects in water. Fluoride causes damages to the bones of humans and marks the teeth (DWAF, 1996).

2.7.11 Nitrate (NO_{3}-N)

Sand mining does not contribute to elevated nitrate levels in the river, however the sources of it can emanate from the wastewater treatment works, agriculture, pit latrines, human faeces, decomposed animals, mining (coal, platinum, chrome or gold) and industries discharges into the river. Nitrate is measured in milligrams per litre (mg/l) and it is the product of ammonia (DWAF, 1996). The process involves nitrification where there is oxidation of ammonia to nitrite and nitrite to nitrate. Once consumed, the water that is contaminated with nitrates will cause severe toxic effects in infants (DWAF, 1996).

2.7.12 Total alkalinity ($CaCO_3$)

The river can contain alkalinity naturally, which is found in the rocks and soils and can range from low to high in milligrams per litre (mg/l). Sand mining has a significant contribution to a rise to alkalinity as the conductivity increases due to high suspended solids in the water. Alkalinity is present in water naturally. Water in the river, which has more than four pH value, has a high alkalinity. However, the discharge from mining and industries inflow into the river can neutralise the alkalinity (DWAF, 1996).

2.7.13 *Escherichia coli* (*E. coli*)

Sand mining does not contribute to an elevation of *E. coli* in a river. *E. coli* results from wastewater treatment works, pit latrines, human's faeces, decomposed cats, dogs and rodents. *E. coli* contains 97% of coliform bacteria, which is found in human faeces. The faecal coliforms are used determine the presence of bacterial pathogens. The bacterial pathogens can be consumed through contaminated drinking water and will lead to diseases such as cholera, typhoid fever etc. Drinking contaminated water with microbial pathogens is a high health risk, which may result in loss of life (DWAF, 1996).

2.7.14 Total coliforms

Sand mining does not contribute to total coliforms in a river; however, the sources can be wastewater treatment works, pit latrines, human's faeces, decomposed cats, dogs and rodents into the River. Total coliforms originate from faecal coliforms; however, some are from the plants and soils. Water consumed with total coliforms can cause diseases such as cholera, typhoid fever, gastroenteritis and salmonella (DWAF, 1996).

2.7.15 Erosion

Sand mining in the river can lead to the deepening and widening of the river channel, which ultimately results in fast flowing water and soil erosion (Ramachandra *et al.,* 2018). The removal of instream and riparian vegetation is a contributor to erosion of the river and its riverbanks. Erosion in a river can also occur naturally as the rocks and sediments are transported during rainy seasons and wind, and deposited in other sections of the river (Romy, 2014).

2.7.16 Macroinvertebrates

Macroinvertebrates are large to be seen with an unaided eye and do not have a backbone (Dickens and Graham, 2002). They are used as bio-indicators to determine ecological status of the aquatic environments. Sand mining has negative impacts on the macroinvertebrates as it involves changes in water quality, quantity and removes the instream and riparian vegetation (Dickens and Graham, 2002). Macroinvertebrates families that may be found in any surface water resources namely *Ephemeroptera-Mayflies, Trichoptera-caddisflies, Caseless Caddisflies, and Cased Caddisflies, Coleoptera-Bettles, Hemiptera-Bugs, Adonata-dragonflies, Zygoptera-Damselflies, Diptera-flies, Lepidoptera, Turbellaria, Plecoptera, Hydracarina, Megaloptera, Crustacea, Porifera, Annelida, Mollusca-snails and Limpets* (Gerber and Gabriel, 2002).

The advantages of using macroinvertebrates as bio-indicators to determine the ecological status of a river, are as follows:

- they can be affected by the physical, chemical, and biological conditions of the river,
- they cannot escape pollution and show the effects of short- and long-term pollution,
- they may show the cumulative impacts of pollution impacts from habitat loss not detected by other water quality assessments,
- and some are very intolerant to pollution and are easy to sample and identify (Gerber and Gabriel, 2002).

However, there are also disadvantages which include:

- no flow in the water resources,
- less habitats in the river to sample,
- inaccessibility of monitoring points for sampling,
- and heavy rainfall, which causes dilution of the water in a river during assessment.

2.7.17 Vegetation

According to the study by Ramachandra *et al.* (2018), sand mining disturbs the habitat by removal of riparian and marginal vegetation, which result in loss of aquatic species. The Sand mining involves complete removal of instream and riparian vegetation. The removal of vegetation from the river destabilises the riverbanks and destroys the soil profile, which influences negatively on the habitats of the species in the ecosystem. The removal of vegetation on the surface land next to the river for sand stockpiling and access roads, by human activities, reduce land use/cover in the ecosystem (Roth, 1996).

2.7.18 Riverbanks

The study by Ramachandra *et al.* (2018) indicates that sand mining result in impacts of erosion on the riverbanks, unstable and collapsed riverbanks. Sand mining affects the riverbanks, as riparian vegetation within the banks is removed with the use of machines. The riverbanks destabilise which lead to increase erosion of the River. As erosion occurs within a river, riverbanks collapse which, result in eco-systems overloaded with sediments (Smith and Collis, 1993).

2.7.19 Adjacent land and structures

Removal of instream and riparian vegetation during sand mining, result in high erosion in the river, which causes the riverbanks to collapse and instability of the riverbed (Ramachandra *et al.,* 2018). The adjacent land and structures are affected negatively as the river morphology changes due to sand mining. The deep and widened river allows water to flow fast during heavy rainfall and floods, which result in the water to flood the adjacent land and structures (Smith and Collis, 1993).

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CHAPTER 3
MATERIALS AND METHODS

3.1 Location of study area

The Mokolo River is the largest water resource in Limpopo Province of South Africa as the catchment stretches for approximately 8 387 m^2 (DWAF, 1996). The Mokolo River forms part of Limpopo Water Management Area (LWMA) and consists of tertiary basin A42 that includes quaternary catchments A42C-A42J (Seaman *et al*., 2013). The whole catchment of the Mokolo River starts from the Waterberg Mountains and passes through Sand River (Fig. 3.1) (Seaman *et al*., 2013). The Mokolo River starts flowing from the town of Alma for 1.5 km which then confluences with the Sand River and the Grootspruit, where after it continues flowing towards the Vaalwater town. The river continues flowing in low veld flat areas until it connects to the Mokolo Dam. The Mokolo Dam is upstream of the Mokolo River that captures more water before it continues flowing downstream.

Mokolo Dam is the largest in the Water Management Area. It was constructed in 1970s with a full supply capacity of about 146 million m^3. Mokolo Dam supplies the Lephalale town, industries, mining and agricultural activities, and nearby communities with water (Fig. 3.2). The water levels in the dam have dropped to 23 million m^3/a because of high demand and supply. The downstream water users receive less water within the Mokolo River as there is too much demand of water from Mokolo Dam (Seaman *et al*., 2013). The flow of water in the Mokolo River has changed over years because of high abstraction, evaporation and physical disturbances as result of sand mining activities within the River. Therefore, the Mokolo River only flows seasonally, and it has changed from perennial to non-perennial due to the loss of connectivity (Seaman *et al*., 2013).

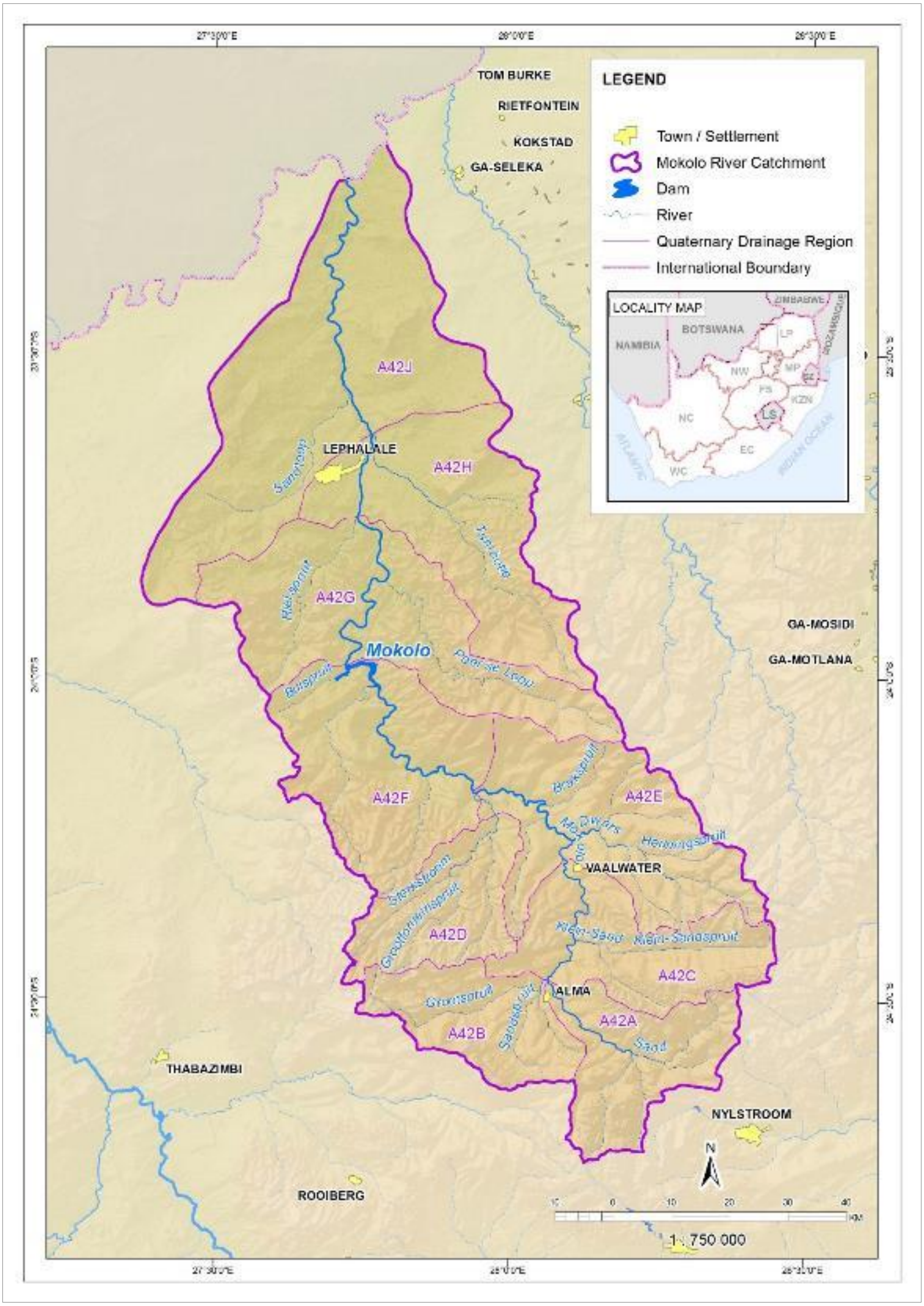

Figure 3.1: The Mokolo River catchment area (DWS, 2017)

Figure 3.2: Map showing sand mining activity in the Mokolo River (Google Earth, 2018)

3.2 Climate and geology

The temperature in the Lephalale area is very hot with high evaporation. The rainfall varies between 250 mm and 500 mm, and annual average precipitation is about 435 mm (Seaman *et al*., 2013).

According to Seaman *et al*. (2013), the geology of the Mokolo River catchment (also known as Mokolo catchment) consists of sandstone and mudstone of the Waterberg Group and Karoo Super Group, with the local outcrops of conglomerate and dolerite. Calcrete, ferricrete, gravel red sand and alluvium sediments are also present within the Mokolo catchment (Seaman *et al*., 2013). The river consists of coarse sandy alluvium with a thickness of 5 metres and it functions as a local aquifer during rainy seasons to the groundwater. The high presence of sandstones in Mokolo catchment, increase the sediments from the hill slopes into the rivers, which is dominated by sand with low silt content (Seaman *et al*., 2013).

Waterberg sandstone rocks were formed many years ago by rivers, which drained from the mountainous areas. The sediments, which were deposited by those rivers, became well sorted over a long period and resulting in high sand material in the rivers (Seaman *et al*., 2013). The Waterberg sediments are reddish in colour due to the presence of iron oxides. They were formed due to the presence of free oxygen (Seaman *et al*., 2013). Sand mining in the Mokolo River stretches for approximately 20 km at the lower Mokolo River.

3.3 Materials

The study used secondary/existing water quality data for physico-chemical and microbial analyses that were analysed by Capricorn Veterinary and Lepelle Northern Water Laboratories, on behalf of the Dept. Water and Sanitation (DWS) as part of water quality monitoring for the Mokolo River. The water quality samples for the existing data were collected between the periods of September 2013 to December 2016. The study also used primary water quality data for physico-chemical and microbial analyses that was collected between the periods of March 2018 to December 2018 and analyses were done by Capricorn Veterinary Laboratories which is part of the water quality monitoring for the studies. River health assessment was conducted at upstream, sand mining and downstream areas of Mokolo River using macroinvertebrates as biological indicators in March 2018 and November 2018. Physical observations of sand mining impacts on the Mokolo River were recorded and pictures were taken.

3.4 Methods

This section begins by summarizing the research questions, methods used and the justification of this study in a table format (Table 3.1).

Table 3.1: Research procedure and methodology

Research questions		Method used	Justification
(i)	Does the change in water quality due to sand mining have an impact on the ecology upstream and downstream of the Mokolo River?	The National Chemical Monitoring Programme (NCMP) and the National Microbial Monitoring Programme (NMMP) were used to determine the water quality of Mokolo River.	The Department of Water and Sanitation as the custodian and regulator for all water resources in South Africa developed programmes such as the NCMP (Hohls *et al.*, 2002) and the (NMMP) (DWAF, 2002) to monitor the water quality for the water resources.
(ii)	Does the sand mining have impacts on macroinverte-brates, vegetation, riverbed and banks upstream and downstream of the Mokolo River?	The River Health Programme was used and South African Scoring System Version 5 (SASS5) rapid bio-assessment index method.	According to Chutter (1998) River Health Programme is a national bio monitoring programme that collects, collates and distributes information on the overall ecological status (or healthiness) of the ecosystems of rivers in South Africa. According to Dickens and Graham (2002) the South African Scoring System Version 5 (SASS5) rapid bio-assessment index method is the suitable for assessment of the macroinvertebrates in the river.
(iii)	What are ecological impacts of sand mining in the Mokolo River and environmental mitigation measures in place to minimise such impacts?	The ecological impacts of sand mining in Mokolo River were identified through the water quality, macroinvertebrates and physical characteristics. No environmental mitigation measures were identified during the physical observations.	According to the study by Musonge *et al.* (2019), the deterioration of water quality in rivers has negative impacts on the macroinvertebrates. According to study by Barman *et al.* (2017) sand mining caused change in physical characteristics of a river.

3.4.1 Water quality

Water samples for physico-chemical and microbial analyses were collected up-stream and downstream of sand mining area at the Mokolo River. The water samples were collected at the centre of the river where there was a flow. The water samples for chemical analyses were collected using sterilised 1 litre plastic bottles and water samples for microbial were collected using sterilised 330 ml bottles. The chemical and microbial water samples were collected without any interruption of the flow of water in the river and filled to the brim. The microbial sample was not allowed to overflow and not touched the inner layer of the sampling bottle. The microbial samples and chemical samples were stored in cooler box at 4ºC for cooling and were stored away from direct sunlight and transported to the laboratory on same day of the sampling for analysis.

The following variables were selected based on the activities such as sand mining, industries, wastewater treatment works, coal mining and human domestic activities such as washing, recreational and agriculture, which are occurring within the Mokolo River catchment. The following water quality variables were analysed by the laboratories.

The pH and electrical conductivity (EC) were analysed using a laboratory combo metre (Metrohm Co. Model 713 and Hach Co. Sension7). The sample container was rinsed with deionised water and then rinsed three times with the sampled water from the Mokolo River. The sampled water was then poured into the sample container for measurements of pH and EC using the laboratory combo metre. The measurements of pH and EC were recorded.

The turbidity was determined using the nephelometric method (APHA, 1998). Turbidity was measured using nephelometer by assessing the amount of light scattered in sampled water (Fondriest Staff, 2010). The water sample was poured on the sample cell of the nephelometer and no air bubbles were formed, then the sample cell was turned two to three times to ensure that the suspension is constant (Fondriest Staff, 2010). The sample cell was then inserted into the nephelometer and the measurements were recorded in Nephelometric Turbidity Units (NTU).

The calcium, potassium, sodium and magnesium were determined by using the atomic absorption spectrophotometry method (APHA, 1998). The deionised water was added to the beakers for each variable and stock solutions or reagents (calcium solution, magnesium solution, potassium chloride solution and sodium chloride solution) were added using pipette, then the solution was mixed thoroughly (Desissa, 2014). The flame atomic spectrophotometric was set and the absorbance was measured (Desissa, 2014). The results of the measurements of calcium, potassium, sodium and magnesium were then recorded.

Chloride was determined using the Argentometric method (APHA, 1998). The water sample was added into flask and then potassium chromate indicator solution was added to the water sample. The solution was then titrated with silver nitrate solution and the chloride ion concentration was calculated (APHA, 1998). The measurements of the chloride were then recorded.

Fluoride was determined using the photometric method (APHA, 1998). The water sample was poured into a tube and then distilled water was then added, then added a reagent to all the tubes and wait for reaction (APHA, 1998). The solutions are then filled into separate semi-microcells and the fluoride was measured in photometer (APHA, 1998). The measurements of the chloride were then recorded.

The nitrate was determined by using the spectrophotometric method (APHA, 1998). The nitrate stock solution or reagent was pipette into the beakers, added the concentration of hydrogen chloride and sodium chloride and the mixture was stirred and allowed to settle for thirty minutes. Then, the stock solution was filtered into the flask through a filter paper and diluted (Badiadka and Kenchaiah, 2009). The stock solution of reduced nitrate was poured into a series flask and then sulphanilic acid, hydrogen chloride solutions were added, and then the solution was shaken for five minutes for the diazotization reaction to be completed (Badiadka and Kenchaiah, 2009). Methyl anthranilate and sodium hydroxide solutions were added to form azo dye and the solution was diluted with water (Badiadka and Kenchaiah, 2009). After the dilution, the absorbance of the red dye was measured and the measurements of nitrate were then recorded.

Sulphate was determined by using the turbidimetric method (APHA, 1998). Buffer solutions of a mixture of magnesium chloride, sodium chloride, potassium nitrate and acetic acid into distilled water and fill up to the mark of the flask. Standard sulphate solution was made (APHA, 1998). The water sample was filtered through a filter paper into flask and then the buffer solution was added, then barium chloride was added to the sample and the mixture was stirred for one hour (APHA, 1998). The absorbance of the solution was measured and sulphate calibration curve was plotted, then concentration of the sulphate was determined (APHA, 1998). The measurements of sulphate were then recorded.

Total alkalinity was determined by the potentiometric titration method (APHA, 1998). Alkalinity reagents (phenolphthalein indicator and sulphuric acid) were prepared (APHA, 1998). The phenolphthalein indicator drops were added to the water sample of 50 ml, the sample was titrated with sulphuric acid to pH 8.3, and the phenolphthalein alkalinity was estimated. The same solution was added with drops of bromocresol green indicator and titrated with sulphuric acid to pH 4.5, and the total alkalinity was estimated. The amount of acid that was used is reacting with hydroxide, carbonate and bicarbonate and it gives the total alkalinity. The measurements of total alkalinity were then recorded.

The total coliforms and *Escherichia coli* (*E. coli*) were determined using the Colilert test method (APHA, 2004). The water sample was mixed with one packet of Colilert reagent. The solution was then mixed thoroughly to ensure that the reagent is dissolved. The mixture was then poured into the incubation tray and incubated for 24 hours at 35ºC (APHA, 2004). Large and small wells, which appeared as fluoresce under a long wave ultraviolet light, were *E. coli* and those, which appeared yellow under the ambient light, were total coliforms (APHA, 2004). The measurements of *E. coli* and total coliforms were then recorded.

The laboratories used the following test method codes for water quality analysis, as shown in Table 3.2.

Table 3.2: Laboratory variables and test method codes

Variables	Test methods code
pH	CH-METH-001
Electrical conductivity	CH-METH-002
Turbidity	CH-METH-004
$CaCo_3$	CH-METH-054
Calcium	CH-METH-020
Magnesium	CH-METH-020
Potassium	CH-METH-020
Sodium	CH-METH-020
Chloride	CH-METH-050
Fluoride	CH-METH-013
Nitrate	CH-METH-050
Sulphate	CH-METH-050
E. coli	MI-METH-011
Total coliforms	MI-METH-011

After testing of the water quality in the laboratory, the water quality test results were compiled. The water quality results were plotted on the graphs for each variable from the year 2013 to 2018. The results were measured against the water quality limits as per the SAWQG suitable for all users which the limits are populated on the Target Water Quality Guideline (TWQG). The TWQG was used for analysis of data to determine if the water quality is acceptable or not acceptable to all the water users in the Mokolo River catchment.

3.4.2 Macroinvertebrates

Macroinvertebrates were sampled using South African Scoring System Version 5 (SASS5) rapid bio-assessment index method (Dickens and Graham, 2002) at identified monitoring sites (upstream, mining area and downstream) of sand mining area in the Mokolo River. At all the identified sites the habitats were sampled using SASS5 sampling protocol (Dickens and Graham, 2002). A stopwatch was used during the river health assessment, and the assessment was timed for one minute. A kick-net of 300 x 300 mm and 1 mm of mesh size were used in two groups of habitats: Vegetation (V) and Gravel, Sand and Mud (GSM), which were present in the Mokolo River (Dickens and Graham, 2002). Stones (S) (Stone-in-Current (SIC) and Stone-Out-Of-Current (SOOC) were not present in the Mokolo River to sample.

Marginal Vegetation (MV) and submerged vegetation were sampled by holding the net perpendicular to the vegetation, sweeping back and forth and pushing the net under water against and amongst the vegetation for 1 minute in area of 1 m^2. The GSM was sampled by stirring the water with the sampler's feet and sweeping for 1 minute. After sampling each biotope separated by habitats were poured into two different trays (Dickens and Graham, 2002). Magnifying glass and naked eyes were used to identify the macroinvertebrates (Dickens and Graham, 2002).

The macroinvertebrates were identified using the Aquatic Invertebrates of South African Rivers Illustrations Book (Gerber and Gabriel, 2002) and recorded on the SASS5 score sheet. The SASS5 rapid bioassessment index assigns scores to taxa, based on perceived sensitivity to water quality impairment. The sensitivity scale was derived from the tolerance to pollution (Dickens and Graham, 2002).

The 1 to 5 scores on the sensitivity scale indicates that identified macroinvertebrates are highly tolerant to pollution, 6 to 10 moderately tolerant to pollution and 11 to 15 very low tolerance to pollution (Gerber and Gabriel, 2002). Therefore, the highest score, 15, represents sensitive taxa which is not tolerant to pollution and the lowest score, 1, represents tolerant taxa to pollution (Gerber and Gabriel, 2002).

The SASS score is the sum of the taxa scores identified from the sample and the number of taxa is the sum of families identified from the sample (Dickens and Graham, 2002). The Average Score per Taxon (ASPT) was derived by SASS score divided by the total number of taxa. Dallas (2007) developed a method to generate biological bands for SASS5 Score and ASPT values for each spatial group. The method used natural variation in SASS5 Scores and ASPT at reference sites within a spatial group to determine the percentiles and bandwidths (Dallas, 2007).

The SASS score and ASPT values were plotted against the biological bands of Limpopo Plain (Dallas, 2007) as a reference site to determine the Present Ecological Status (PES) of the Mokolo River. The PES is expressed in terms of biological responses to the aquatic invertebrates (Dallas, 2007). The scale for interpreting SASS data was used to determine the ecological status of the Mokolo River. Table 3.3 describes five different states of health, from an A class (natural) to an E/F class (unacceptable) (Dallas, 2007). The results of applying the biological and habitat indices during a river survey provide the contexts for determining the degree of ecological modification at the monitoring site. Thus, the degree of modification observed at a monitoring site translates into PES (Dallas, 2007).

Table 3.3: Biological bands / Ecological categories for interpreting SASS data (Dallas, 2007)

Class	Ecological state of the River	Description
A	Natural	No measurable modification
B	Good	Largely unmodified
C	Fair	Moderately modified
D	Poor	Largely modified
E/F	Unacceptable	Seriously modified

3.4.3 Physical characteristics

A PowerShot SX60 HS Canon Camera was used to take pictures for any activities around the river, erosion, removal of vegetation, stockpiling, disturbance of riverbanks and adjacent land and structures in the Mokolo River. Pictures were taken at upstream, sand mining and downstream areas in the Mokolo River. The physical observations of ecological impacts on the Mokolo River were identified, using the naked eye. These include observations of: (1) the destabilised and collapsed riverbanks, (2) the loss of adjacent land, (3) erosion at the sand mining area and disturbed riverbed (4) clearance of vegetation (marginal and riparian vegetation) and (5) deepened and widened river, water pools, (6) river diversions, (7) sand stockpiles within the river and on the nearby land surface and these observations were recorded.

Ethical clearance for this study was obtained from the University of South Africa (UNISA). The Health Research Ethics Committee (HREC), of the College of Agriculture and Environment Sciences (CAES**),** ethically approved this research on the 15th January 2018 with the reference number 2017/CAES/189 (Appendix B).

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CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Water quality for the Mokolo River

The highest number of water users in the catchment are agricultural activities, which produce tobacco, sorghum, maize and sunflower (Seaman *et al*., 2013). The agricultural activities present in the catchment use 87% of the water in the Mokolo River (DWAF, 1992). Other water demanding activities within the Mokolo River catchment includes mining and industries (e.g. Grootegeluk, Thabametsi and Boikarabelo [Ledjadja] Coal Mines, Medupi and Matimba Power Stations). The activities such as sand mining, coal power stations, coalmines, guest lodges, golf course, wastewater treatment works, petrol stations and agricultural activities are within the catchment of the Mokolo River. All the activities and communities in the catchment use water from the Mokolo River. The Mokolo River has changed from perennial to non-perennial because of high abstraction of water and evaporation, farmers building instream dams and preventing flow of water (Seaman *et al*., 2013). During the dry season, there were some portions of the river, where water was stagnant due to instream dams, instream sand stockpiles and river diversions, which resulted in no flow of water; Therefore, during the studies period, the Mokolo River was flowing during wet seasons and no flow in dry seasons.

The water quality results upstream and downstream of the Mokolo River were interpreted against the requirements in the South African Water Quality Guidelines (SAWQG). The requirements are tabulated on the Target Water Quality Guideline (TWQG) for all water users, which is based on Volume 1 - Domestic use (DWAF, 1996a), Volume 3 - Industrial use (DWAF, 1996b), Volume 4 - Agricultural use, Irrigation (DWAF, 1996c), Volume 6 - Agricultural water use, Aquaculture (DWAF, 1996d), Volume 7 - Aquatic ecosystems (DWAF, 1996e) and Volume 8 - Field guide (DWAF, 1996f). The water quality results for upstream and downstream of the Mokolo River are tabulated on Tables C.1 and C.2 and the results that are over the limit, as per the TWQG for all water users, are in red (Appendix C).

The water quality for upstream and downstream of the Mokolo River was found to be good as per the TWQG standard, except for some of the variables that were over the limits. The water quality results for pH, electrical conductivity (EC), total alkalinity, sodium, calcium, magnesium, potassium, chloride, fluoride, sulphate and nitrate were not over the limits as per the requirements of the TWQG from the year 2013-2018. The water quality results for turbidity, total coliforms and *Escherichia coli* (*E. coli*) were over the limits as per the requirements of the TWQG from the year 2013 to 2018. The graphs below indicate the water quality for downstream and upstream of the Mokolo River as per each variable from the year 2013 to 2018.

The pH was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River (Fig. 4.1). The pH was ranging 6.8 to 7.9 from the year 2013 to 2018, which indicates neutrality of the water in the Mokolo River. There was small variance in pH throughout the years; however, it does not have a negative impact on the water quality of the Mokolo River. Sand mining and other activities in the catchment of the Mokolo River do not influence the pH; therefore, pH does not have a negative impact on the ecology of the Mokolo River.

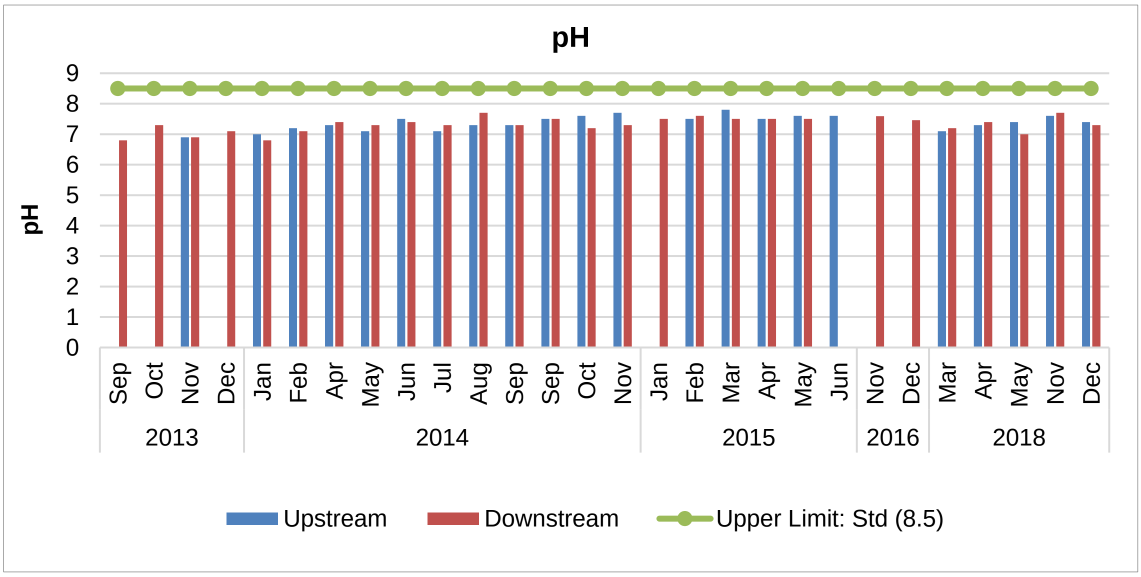

Figure 4.1: pH (content upstream and downstream of the Mokolo River)

The EC was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was variance of EC throughout the years, however, does not have negative impact on the water quality of the Mokolo River

(Fig. 4.2). There was surface water run-off with salts from the farming area into the river during high rainfall and floods, which resulted into significant increase of EC in October 2018; however, the EC is still within the limits. Sand mining and other activities in the catchment of the Mokolo River do not influence the EC; therefore, EC does not have a negative impact on the ecology of the Mokolo River.

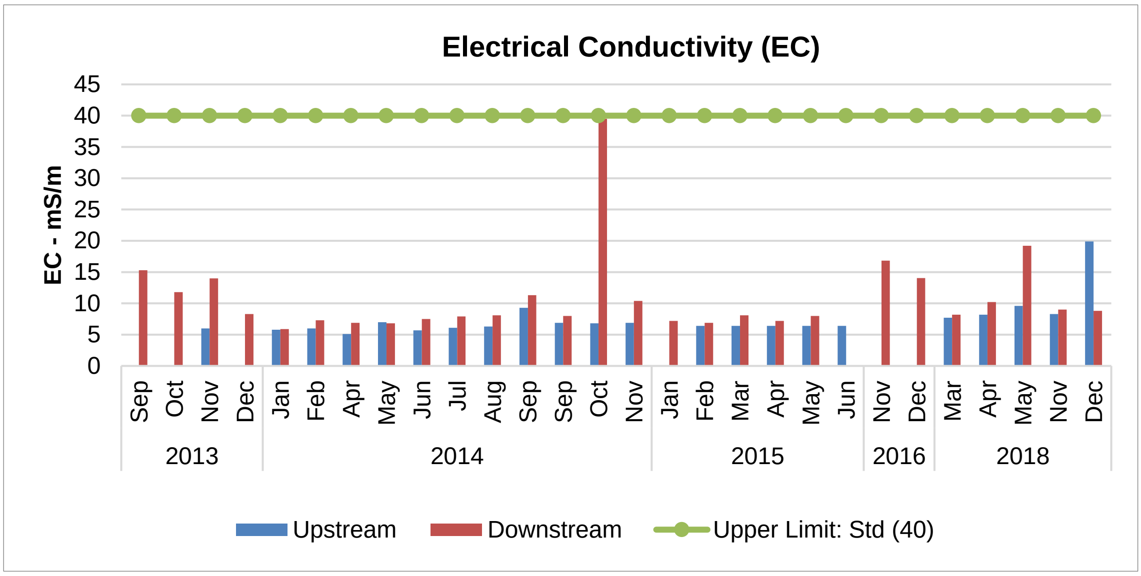

Figure 4.2: Electrical conductivity (content upstream and downstream of the Mokolo River)

Turbidity was over the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. During the year 2013, 2014 and 2015 there was significant increase in turbidity at upstream (Fig. 4.3). The increased turbidity at upstream occurred during rainy seasons as result of increased sedimentation load in the river. There were heavy rains, which started in November 2013 and continued until January 2014 and resulted in floods thus increased turbidity at upstream area. There was significant increase in turbidity at downstream area in March 2018. Turbidity decreased from April to December 2018 at the downstream area, as there was no high flow of water to carry sediments from sand mining area to the downstream area. The turbidity was higher downstream than upstream for some of years as result of sand mining. Turbidity was caused naturally in the river as the system erodes during rainy seasons and floods through the transportation of sediments and caused by sand mining in the study area, which increased sediments in the Mokolo River, thus, increased turbidity upstream and downstream. Turbidity has a negative impact on the ecology of the Mokolo River and result in loss of macroinvertebrates.

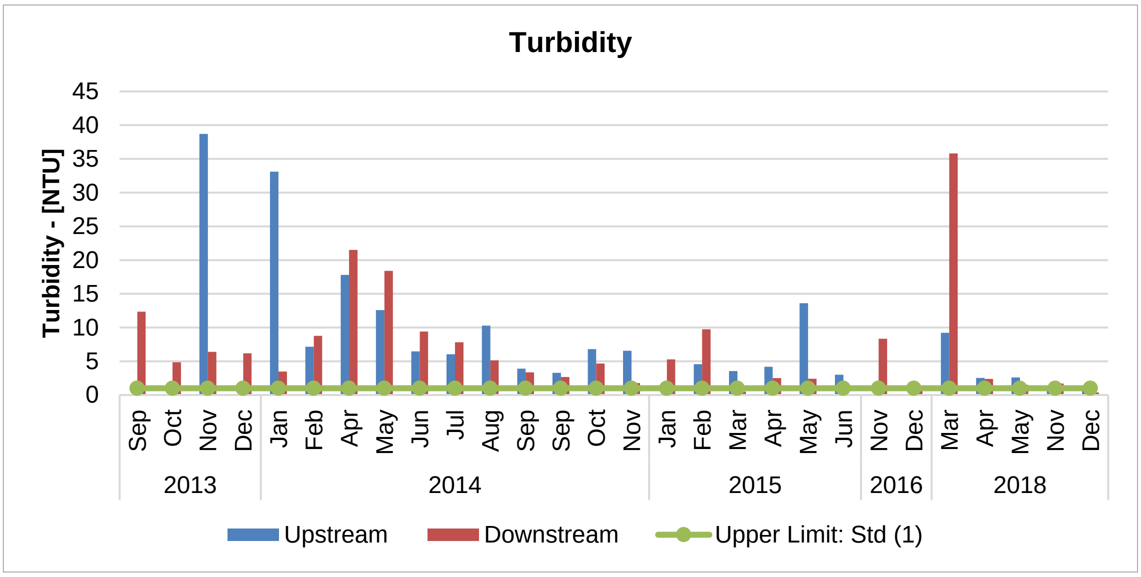

Figure 4.3: Turbidity (content upstream and downstream of the Mokolo River)

Fluoride was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. Sand mining and other activities in the catchment of the Mokolo River do not influence the fluoride (Fig. 4.4). There was very small variance in fluoride throughout the years; however, it does not have a negative impact on the ecology of the Mokolo River.

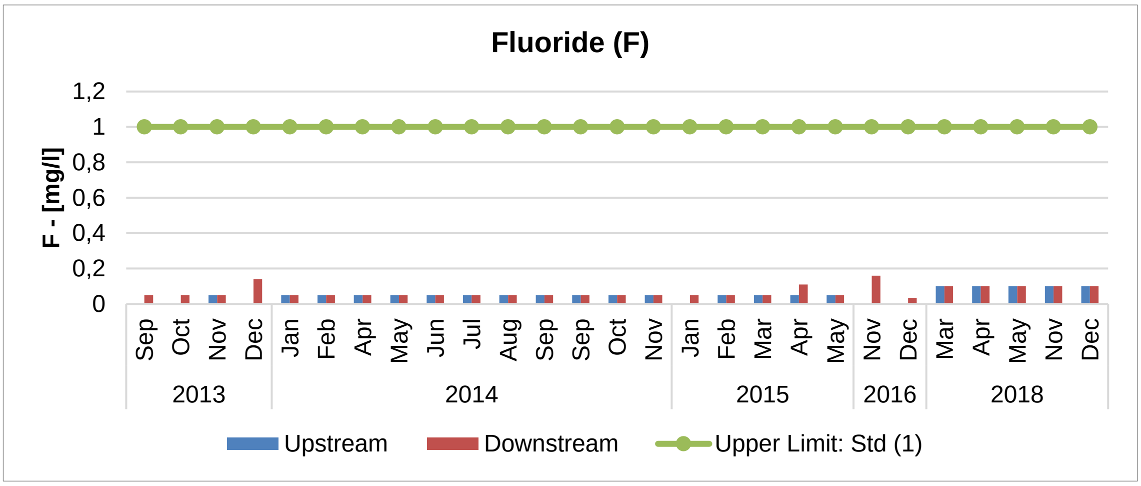

Figure 4.4: Fluoride (content upstream and downstream of the Mokolo River)

Total Alkalinity was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was an increase in total alkalinity in October 2014 at upstream due to floods (Fig. 4.5). Sand mining and other activities in the catchment of the Mokolo River do not influence the total alkalinity. There was a small variance in total alkalinity throughout the years; however, it does not have a negative impact on the ecology of the Mokolo River.

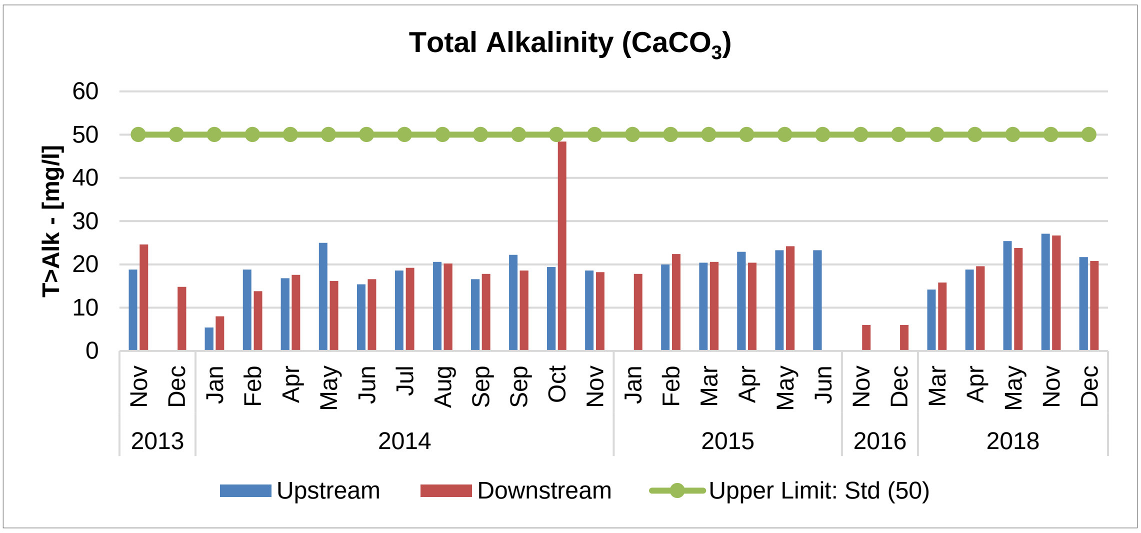

Figure 4.5: Total alkalinity (content upstream and downstream of the Mokolo River)

Sodium was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was a significant increase in October 2014, and May and December 2018 at upstream and downstream areas due to surface water run-off from the farming area into the river during rainy season and floods (Fig. 4.6). Sand mining and other activities, except agricultural activity within the catchment of the Mokolo River of this study do not influence the sodium. There was small variance in sodium throughout the years; however, it does not have a negative impact on the ecology of the Mokolo River.

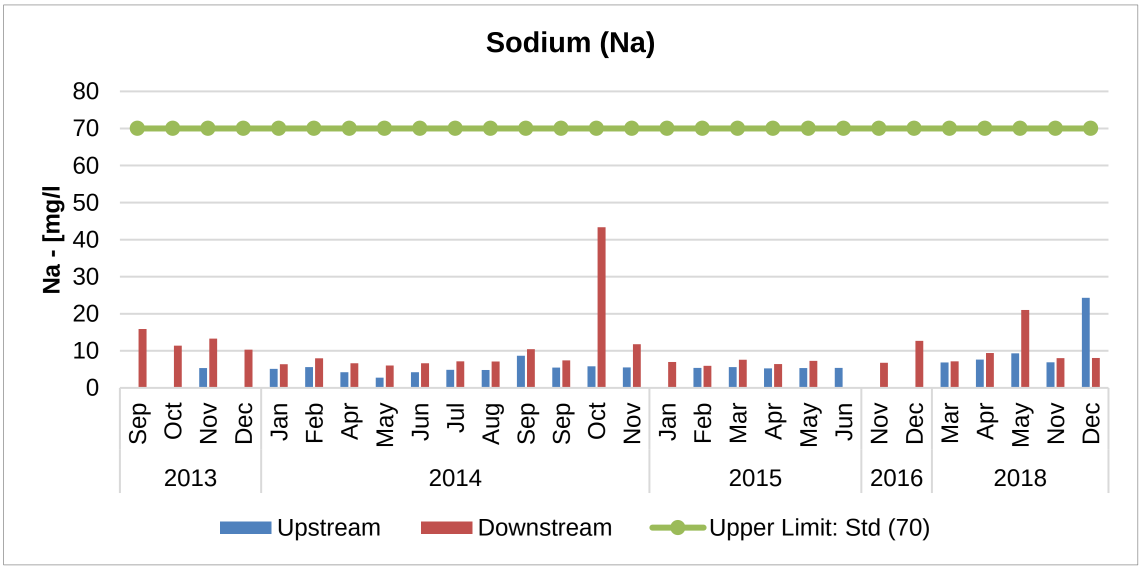

Figure 4.6: Sodium (content upstream and downstream of the Mokolo River)

Magnesium is within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was an increase in October 2014 at downstream due to floods and surface water run-off from the farming area (Fig. 4.7). Sand mining and other activities, except agricultural activity within the catchment of the Mokolo River of this study do not influence the magnesium. There was a very small variance in magnesium throughout the years; however, it does not have a negative impact on the ecology of the Mokolo River.

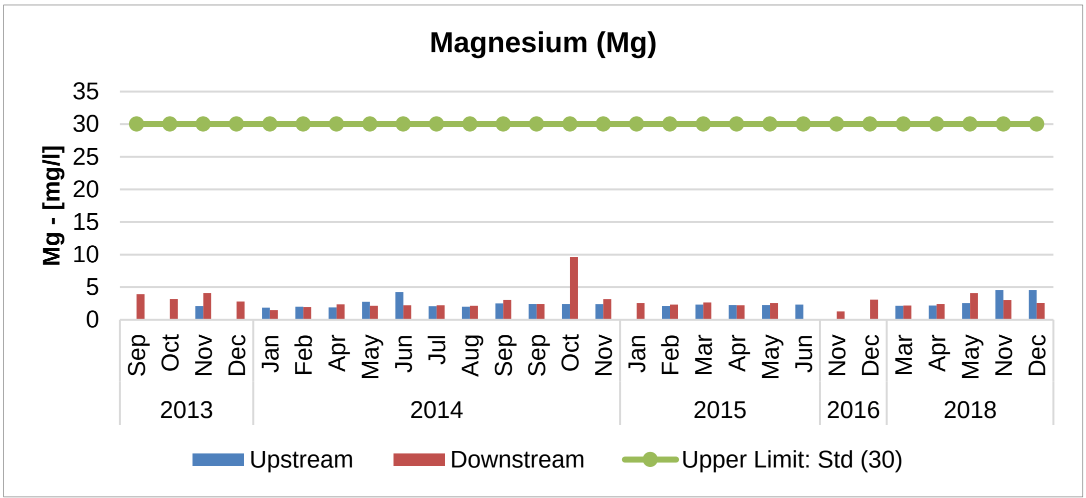

Figure 4.7: Magnesium (content upstream and downstream of the Mokolo River)

Sulphate was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was significant increase in sulphate in October 2014 at upstream due to high rainfall during that period (Fig. 4.8); however, the concentrations remained within the limits. Sand mining and other activities within the catchment of the Mokolo River do not influence the sulphate as the trend remained under the limits. The sulphate does not have a negative impact on the ecology of the Mokolo River.

Chloride was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was significant increase in October 2014 and December 2018 due heavy rainfall and surface water run-off from the farming area into the river (Fig. 4.9); however, the concentrations are within the limits. Sand mining and other activities, except agricultural activity within the catchment of the Mokolo River of this study do not influence the chloride. There was a small variance in chloride throughout the years and does not have a negative impact on the ecology of the Mokolo River.

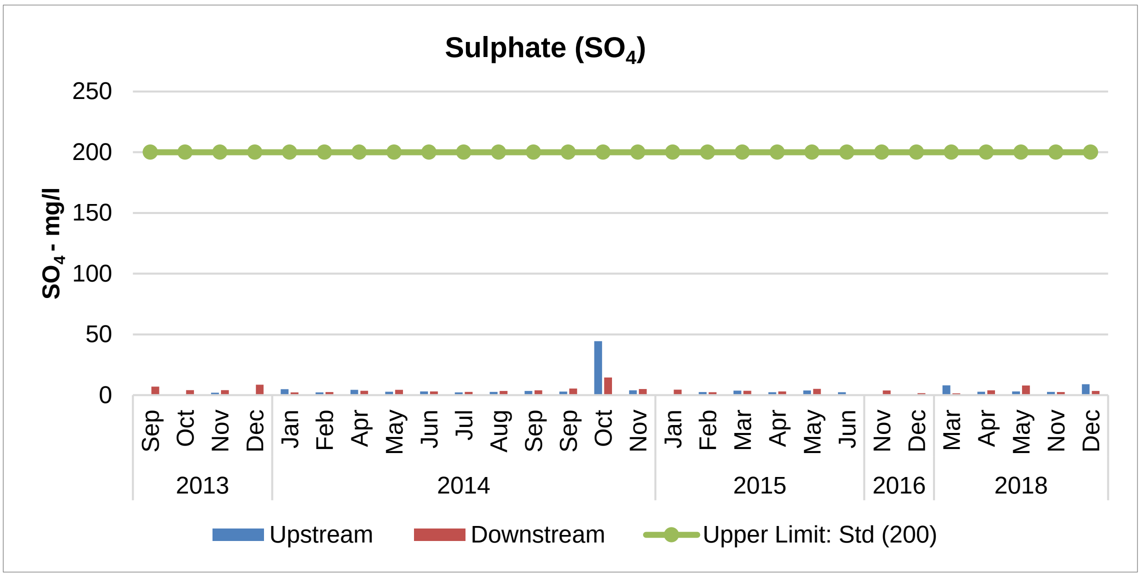

Figure 4.8: Sulphate (content upstream and downstream of the Mokolo River)

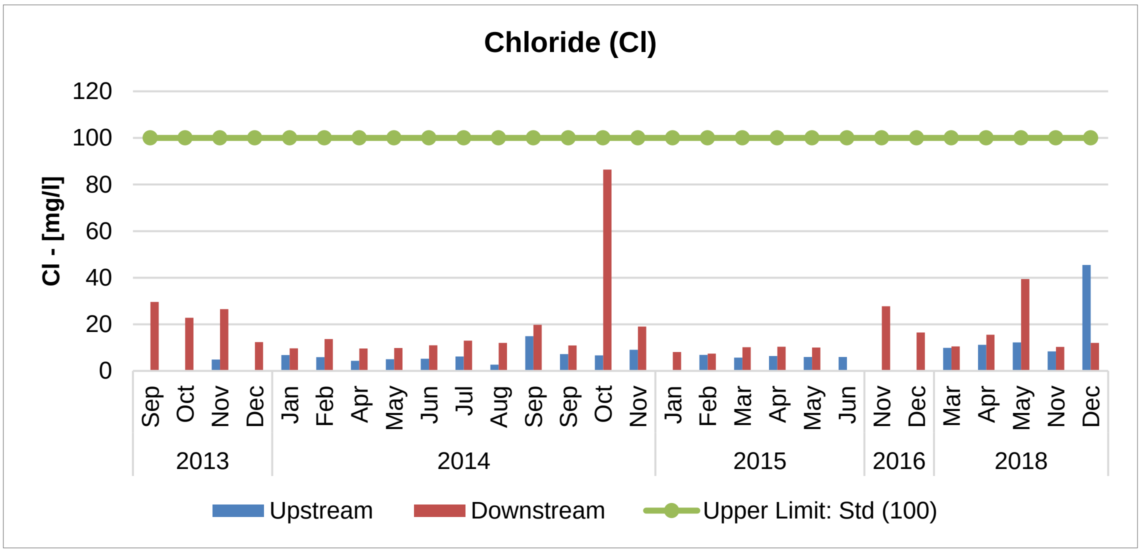

Figure 4.9: Chloride (content upstream and downstream of the Mokolo River)

Potassium was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. Sand mining and other activities in the catchment of the Mokolo River do not influence potassium (Fig. 4.10). The trend remained constant throughout the years with a small variance; however, it does not have a negative impact on the ecology of the Mokolo River.

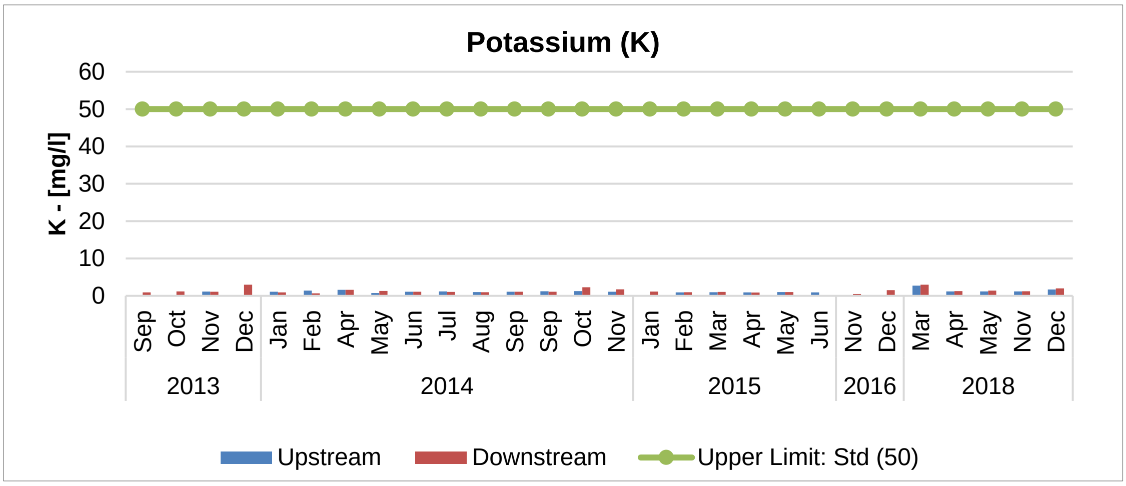

Figure 4.10: Potassium (content upstream and downstream of the Mokolo River)

Calcium was within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was an increase in calcium in October 2014 at downstream area due to surface water run-off, heavy rainfall and floods (Fig. 4.11); however, the concentrations are within the limits. Sand mining and other activities in the catchment of the Mokolo River do not influence the calcium. There was a small variance in calcium throughout the years; however, it does not have a negative impact on the ecology of the Mokolo River.

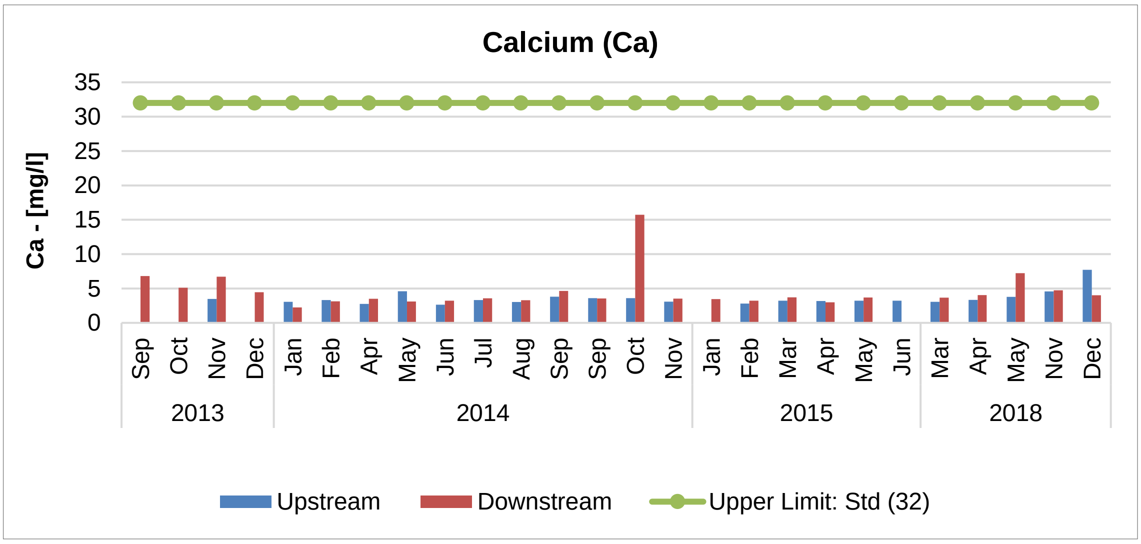

Figure 4.11: Calcium (content upstream and downstream of the Mokolo River)

Nitrate is within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. There was small variance throughout the years and the nitrate was detected to be less than 0.06 mg/l in March, April and May

2018 (Fig. 4.12). Sand mining and other activities within catchment of the Mokolo River of this study do not influence the nitrate. Nitrate does not have negative impact on the ecology of the Mokolo River.

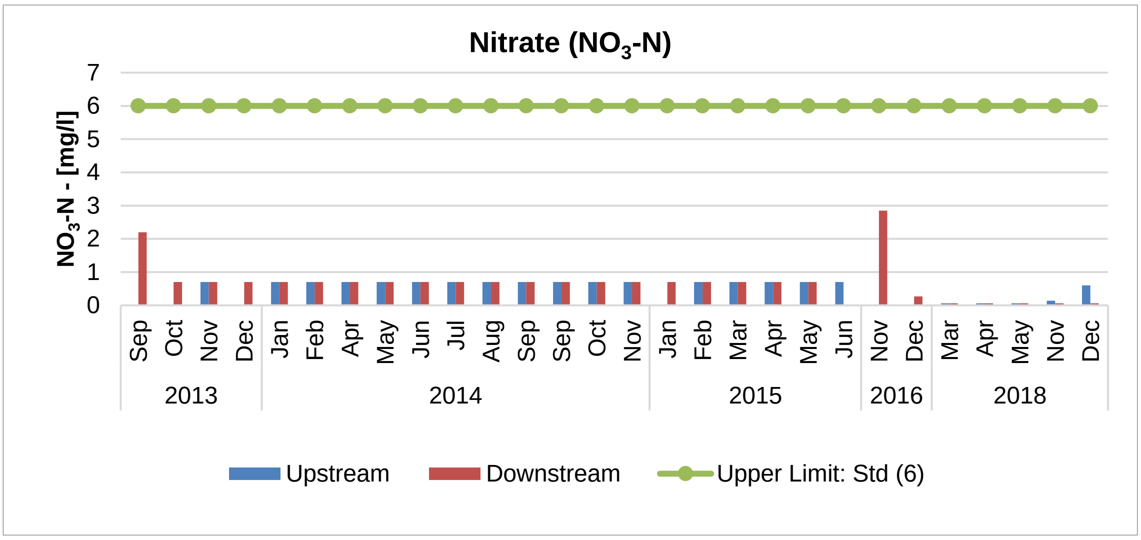

Figure 4.12: Nitrate (content upstream and downstream of the Mokolo River)

Total coliform was not within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. The trend remained constant throughout the years with a small variance (Fig. 4.13). The total coliforms are high in the Mokolo River due to surface water run-off from the agricultural area, human's faeces and disposal of dead animals by communities. Communities also perform traditional rituals in the area as observed during collection of water quality samples, which led to elevated concentrations of total coliforms in the Mokolo River. There are no discharges of final effluent from the wastewater treatment works at the upstream and downstream area of this study. The water in the Mokolo River if consumed without any treatment will cause diseases such as *Cholera, Typhoid fever, Gastroenteritis* and *Salmonellosis.* Sand mining and other activities, except agricultural activity, human faeces, and disposal of dead animals by communities within the catchment of the Mokolo River of this study do not influence the total coliforms. The high total coliforms have negative impact on the ecology of the Mokolo River.

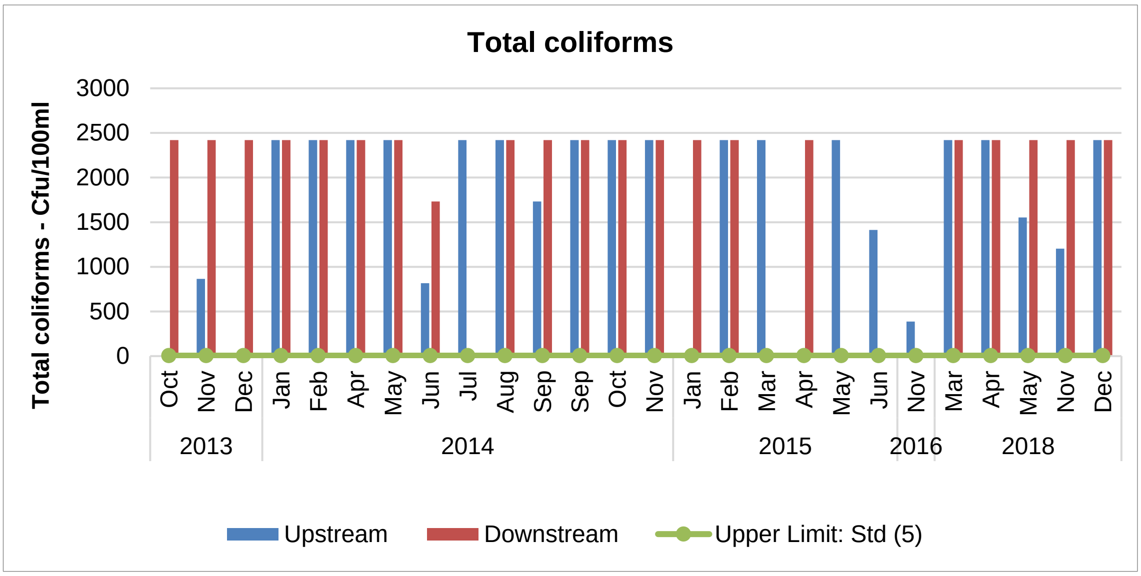

Figure 4.13: Total coliforms (content upstream and downstream of the Mokolo River)

E. coli is not within the TWQG limit from the year 2013 to 2018 at upstream and downstream of the Mokolo River. The trend remained constant throughout the years with a small variance that occurred (Fig. 4.14). The *E. coli* is high in the Mokolo River due surface water run-off from the agricultural area, human's faeces and disposal of dead animals by communities. Sand mining and other activities, except agricultural activity, human faeces and disposal of dead animals by communities within the catchment of the Mokolo River of this study do not influence the *E. coli*. The high *E. coli* has negative impact on the ecology of the Mokolo River.

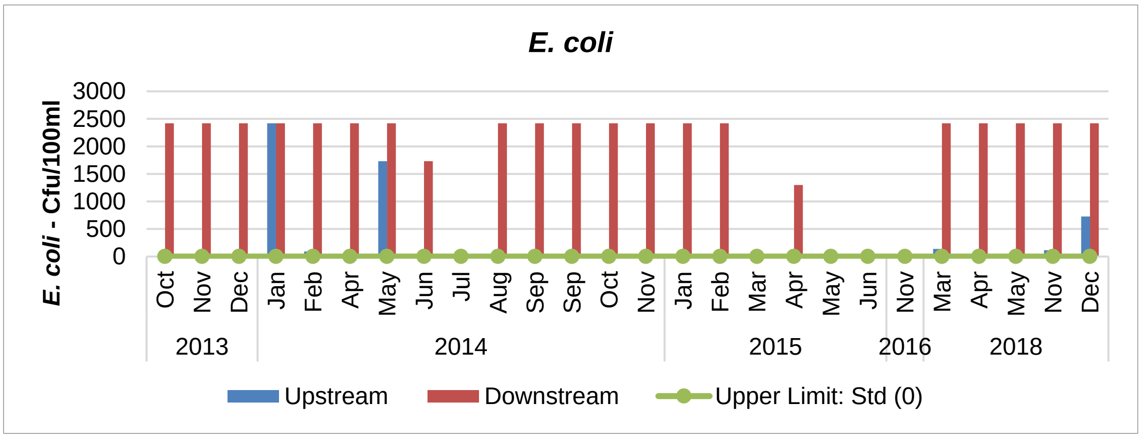

Figure 4.14: *E. coli* (content upstream and downstream of the Mokolo River)

4.1.2 Macroinvertebrates in the Mokolo River

The South African Scoring System version 5 (SASS5) cannot be conducted in rivers, where the water is not flowing or where the water is stagnant. The River Health Programme (RHP) was conducted upstream, sand mining and downstream of the Mokolo River in March 2018 and November 2018 (Appendix D). There were limited taxa (diversity) during the period of this study at the sampling areas in the Mokolo River. The River was dry from June to October 2018 at the upstream and downstream areas as there was no rain for the river to flow. However, at the sand mining area there was different water pools, blocked by the sand stockpiles, which resulted in the water not flowing downstream.

Highly tolerant taxa to pollution such as *Baetidae, Libellulidae, Corixidae, Dytiscidae, Ceratopogonidae and Planorbidae* were found upstream of the Mokolo River. Moderately tolerant taxa to pollution such as *Gomphidae, Hydraenidae and Hydrophilidae* were found at upstream of the Mokolo River. The SASS score is 45, number of taxa is 9 and the Average Score per Taxon (ASPT) score was calculated to be 5 (Table 4.1). The present ecological status at upstream of the Mokolo River falls under class C that is classified fair (moderately modified).

Table 4.1: March 2018 SASS5 results for upstream in the Mokolo River

SASS Score	No. of Taxa	ASPT	Condition
45	9	5	Class C and Fair (moderately modified)

Highly tolerant taxa to pollution such as *Baetidae, Libellulidae, Veliidae, Ceratopogonidae, Chironomidae, Culicidae, Simuliidae and Planorbidae* were found at sand mining area of the Mokolo River. The SASS score is 37, number of taxa is 9 and the ASPT score was calculated to be 4.11 (Table 4.2). The present ecological status at sand mining area of the Mokolo River falls under class E/F that is classified as unacceptable (seriously modified).

Table 4.2: March 2018 SASS5 results for sand mining area in the Mokolo River

SASS Score	No. of Taxa	ASPT	Condition
37	9	4.11	Class E/F and unacceptable (seriously modified)

Highly tolerant taxa to pollution such as *Baetidae, Libellulidae, Corixidae, Belostomatidae, Notonectidae, Gyrinidae* and *Chironomidae* were found downstream of the Mokolo River. Moderately tolerant taxa to pollution such as *Gomphidae, Hydrophilidae,* Ancylidae were found at downstream of the Mokolo River. Very low tolerant to pollution *Helodidae* taxon was found at downstream of the Mokolo River. Fish species were also observed in this area during the assessment. The SASS score is 61, number of taxa is 11 and the ASPT score was calculated to be 5.54 (Table 4.3). The present ecological status at downstream of the Mokolo River falls under class C that is classified as fair (moderately modified).

Table 4.3: March 2018 SASS5 results for downstream in the Mokolo River

SASS Score	No. of Taxa	ASPT	Condition
61	11	5.54	Class C and Fair (moderately modified)

Highly tolerant taxa to pollution such as *Baetidae, Libellulidae, Corixidae, Dytiscidae and Planorbidae* were found upstream of the Mokolo River. Moderately tolerant taxa to pollution such as *Gomphidae, Naucoridae, Hydraenidae, Hydrophilidae* and *Ancylidae* were found at upstream of the Mokolo River. Very low tolerant to pollution *Helodidae* taxon was found at upstream of the Mokolo River. The SASS score is 52, number of taxa is 9 and the ASPT score was calculated to be 5.7 (Table 4.4). The present ecological status at upstream of the Mokolo River falls under class B that is classified as good (largely unmodified). The ecological status at the upstream area changed from class C (March 2018) to class B (November 2018), therefore the ecological status has improved at the upstream of the Mokolo River.

Table 4.4: November 2018 SASS5 results for upstream in the Mokolo River

SASS Score	No. of Taxa	ASPT	Condition
52	9	5.7	Class B Good (largely unmodified)

Highly tolerant taxa to pollution such as *Baetidae, Libellulidae, Veliidae, Ceratopogonidae, Chironomidae, Simuliidae and Gerridae* were found at the sand mining area of the Mokolo River. The SASS score is 32, number of taxa is 7 and the ASPT score was calculated to be 4.5 (Table 4.5). The present ecological status at sand mining area of the Mokolo River it falls under class E/F that is classified as unacceptable (seriously modified). The ecological status at the sand mining area remained seriously modified therefore it indicate that the sand mining, erosions, river diversions, use of machineries and instream sand stockpiles have a negative impact on the macroinvertebrates.

Table 4.5: November 2018 SASS5 results for sand mining area in the Mokolo River

SASS Score	No. of Taxa	ASPT	Condition
32	7	4.5	Class E/F and unacceptable (seriously modified)

Highly tolerant taxa to pollution such as *Baetidae, Corixidae, Nepidae, Veliidae, Notonectidae, Gyrinidae* and *Chironomidae* were found downstream of the Mokolo River. Moderately tolerant taxa to pollution such as *Gomphidae, Hydracarina* and *Hydrophilidae* were found at downstream of the Mokolo River. Very low tolerant to pollution *Helodidae* taxon was found at downstream of the Mokolo River. The SASS score is 64, number of taxa is 11 and the ASPT score was calculated to be 5.8 (Table 4.6). The present ecological status at downstream of the Mokolo River falls under class B that is classified as good (largely unmodified). The ecological status at the downstream area changed from class C (March 2018) to class B (November 2018), therefore the ecological status has improved at the downstream of the Mokolo River.

Table 4.6: November 2018 SASS5 results for downstream in the Mokolo River

SASS Score	No. of Taxa	ASPT	Condition
64	11	5.8	Class B and Good (largely unmodified)

4.1.3 Physical characteristics of the Mokolo River

During the study period, the water in the river was observed to be transparent at the upstream area, tea brown at the sand mining area and light green at the downstream area of the Mokolo River. The water was flowing from upstream through mining area to downstream in the Mokolo River, from January to May 2018, however from June to October 2018, the river was dry and no flow at the upstream and downstream areas.

4.1.3.1 Upstream and downstream of sand mining

There was no sand mining at the upstream and downstream of the Mokolo River. There is no loss of riparian and marginal vegetation, erosion, collapsing of riverbanks, disturbed riverbed, instream sand stockpiles, river diversion and instream dams due to sand mining at the upstream and downstream of the Mokolo River (Figs. 4.15 to 4.19).

Figure 4.15: Upstream area before sand mining

Figure 4.16: River health assessment at upstream area and no sand mining

Figure 4.17: Upstream and no sand mining

Figure 4.18: Downstream area and no sand mining

Figure 4.19: Downstream area and no sand mining impacts

4.1.3.2 After sand mining

During sand mining, there is use of heavy machineries, river diversions are created which diverts natural flow of the water in a river and less water flows to the downstream area (Fig. 4.20 to 4.27). The physical disturbances of removal of riparian and marginal vegetation (Fig. 4.23), erosion and loss of adjacent land, collapsing of riverbanks, disturbed riverbed (Fig. 4.24), water pools and blockage of water flow with sand (Fig. 4.25 and 4.27), river diversions (Fig. 4.26), instream sand stockpiles, instream dams and abstraction were recorded at the sand mining area of the Mokolo River).

Figure 4.20: Sand mining area

Figure 4.21: River health assessment at mining area

Figure 4.22: Mining area and instream sand stockpiles

Figure 4.23: Removal of riparian and marginal vegetation and loss of adjacent land

Figure 4.24: Erosion, undercutting and collapsing of riverbanks at sand mining area

Figure 4.25: Blockage of water flow and instream sand stockpile within the river

Figure 4.26: River diversions and instream sand stockpiles within the river

Figure 4.27: Blockage of flow and pool of water

4.2 Discussions

Water resources protection in South Africa is essential in order to meet human and ecological basic needs. Therefore, efficient water resources monitoring and management is very crucial to ensure pollution prevention and sustainable aquatic ecosystems. The water quality, physical characteristics and presence of sensitive macroinvertebrates in the river are useful indicators in determining the ecological status of the aquatic ecosystems (de Klerk and de Klerk, 2011).

The change in water quality for certain water quality parameters due to sand mining has impact the ecology upstream and downstream of the Mokolo River. The results in this study indicated that. The physical disturbance and change in water quality as a result of sand mining has impacted macroinvertebrates, vegetation, riverbed and banks upstream and downstream of the Mokolo River as indicated by the results of this study. Sand mining resulted in a change of water quality, reduction of macroinvertebrates and physical disturbance of Mokolo River during the period of this study. No environmental mitigation measures were in place to minimise such impacts, at the time of the study.

The Dept. Environmental Affairs and Tourism (DEAT), in Limpopo Province, conducted a SASS5 study in the Mokolo and the Lephalala Rivers (DEAT, 2006). The study focused on SASS5 to determine the water quality and ecological status; however, the study did not include the physical, chemical and microbial characteristics of the water. The study was done at three (3) portions, which included upper, middle and lower regions of the Mokolo and the Lephalala Rivers. According to DEAT (2006), the study conducted in these two rivers, showed high numbers of taxa present in most of the sites within the rivers, which indicate that there is less impacts. However, in some of the sites the habitat of the river was changed due to sand mining which deepened and widened the system and caused high water flow in the Mokolo River (DEAT, 2006).

The water quality of the Mokolo and the Lephalala Rivers was not adversely impacted, but only the aquatic ecosystem was impacted adversely at the sand mining sites (DEAT, 2006). The water quality status reflected the presence of sensitive macroinvertebrate species (e.g. *Heptageniidae, Oligoneuridae and Perlidae)* in the two rivers and it was an indication that the water was of good quality (DEAT, 2006). Fish assemblages were in a relatively good condition in these rivers. The data obtained during the study proved that the Mokolo and the Lephalala Rivers have relatively good water quality, which was confirmed through the presence of certain sensitive macroinvertebrates and fish species (DEAT, 2006). The study indicated that the rivers must be monitored regularly for any detection of deterioration in water quality, which will have impact on the ecology (DEAT, 2006).

The Dept. Water and Sanitation (DWS) in Limpopo conducted River Health Assessment in the Mokolo River in 2016 (DWS, 2016). The samples were dominated by moderately tolerant to highly tolerant taxa to pollution and low sensitive to pollution taxa, which includes (*Oligocheata, Chironomidae, Simuliidae* and *Lymnaeidae*). In accordance with SASS Interpretation Guideline (Dallas, 2007) the state of the Mokolo River was determined to be largely impacted (D class) because of sand mining. The results indicated that at the sand mining sites the aquatic ecosystem were negatively impacted, as less macroinvertebrates were identified in those sites (DWS, 2016). The RHP study indicated that the river was largely impacted at the sand mining sites, which negatively influenced the aquatic ecosystem (DWS, 2016).

This study was conducted at the lower Mokolo River region where sand mining is taking place and divided into three (3) areas, namely upstream, sand mining and downstream areas in the River. The study focus was on the sand mining area and the ecological impacts thereof on the Mokolo River. The study included the physical, chemical and microbial characteristics of the water, physical characteristics and macroinvertebrates in the River. The study used water quality, physical characteristics and macroinvertebrates as the aquatic ecosystem indicator in order to determine the ecological impacts of sand mining.

The water quality for upstream and downstream of the river of this study was found to be good and not adversely affected except for some of the variables which were over the limits as per the requirements of the TWQG. The water quality results at upstream and downstream areas for pH, electrical conductivity, total alkalinity, sodium, calcium, magnesium, potassium, chloride, fluoride, sulphate and nitrate were not over the TWQG standard limits, however the water quality results for turbidity, total coliforms and *E. coli* were over the TWQG standard limits. The pH at upstream and downstream areas was not affected by sand mining (Fig. 4.1).

The electrical conductivity at upstream and downstream areas was not affected by sand mining (Fig. 4.2). The high turbidity at upstream area was due to deposition of sediments during rainy seasons and floods and downstream area was changed due to sand mining as result of high sedimentation load coming from the sand mining area (Fig. 4.3). The study by Walker *et al.* (2018) entailed alluvial aquifer characterisation and resource assessment in a river. It was found that during floods or rainy seasons there is increased sediments into a river as a result of erosion and surface water run-off from the nearby vegetation which contains sediments.

According to the study by Meng *et al.* (2018), water with high turbidity reduces the concentration of dissolved oxygen in a river, which limits the breathing and feeding of the aquatic species in the system. High turbidity in the Mokolo River of this study can cause growth deficiencies, mortalities and loss of macroinvertebrates (Meng *et al.,* 2018). The high turbidity in the river indicates that sand mining has negative impacts on the water quality as more sedimentation load was released from the sand mining area due to physical disturbances. High turbidity in the Mokolo River has negative impacts on the macroinvertebrates, hence low presence of species diversity in the system. At the sand mining area, the colour of the water was tea brown and muddy, which prevents sunlight penetrating the water, therefore the aquatic species, cannot breed and survive at the sand mining area. High turbidity has negative impacts on the ecology (aquatic ecosystem) of the Mokolo River. The study by Barman *et al.* (2017) also indicated that high turbidity and suspended solids in a river reduces the amount of sunlight, which penetrates the water, which leads to loss and migration of the aquatic species.

The fluoride at upstream and downstream areas was not affected by sand mining (Fig. 4.4). The total alkalinity at upstream and downstream areas was not affected by sand mining (Fig. 4.5). The sodium at upstream and downstream areas was not affected by sand mining (Fig. 4.6). The magnesium at upstream and downstream areas was not affected by sand mining (Fig. 4.7). The sulphate at upstream and downstream areas was not affected by sand mining (Fig. 4.8). The chloride at upstream and downstream areas was not affected by sand mining (Fig. 4.9). The potassium at upstream and downstream areas was not affected by sand mining (Fig. 4.10). The calcium at upstream and downstream areas was not affected by sand mining (Fig. 4.11). The nitrate at upstream and downstream areas was not affected by sand mining (Fig. 4.12).

The total coliforms (Fig. 4.13) and *E. coli* (Fig. 4.14) were high at upstream and downstream areas in the Mokolo River. The total coliforms and *E. coli* were high in the Mokolo River due to surface water run-off from the agricultural area, disposal of waste, human faeces and disposal of dead animals by communities. It was observed that the communities perform traditional rituals in the river e.g. slaughtering of chickens, which can contribute to high faecal matter and *E. coli* bacteria in the river. When it rains, faecal matter is collected and washed from the agricultural areas into the river, which contribute to high *E. coli* and total coliforms in the Mokolo River. Sand mining does not influence the total coliforms and *E. coli*.

The water in the Mokolo River of this study area, if consumed without any treatment will cause diseases such as *Cholera*, Typhoid fever, Gastroenteritis and Salmonella due to higher total coliforms and *E. coli.* Total coliforms and *E. coli* found in water require lots of oxygen which means that the bacteria will use all the dissolved oxygen present in the water and then oxygen level will not be available for the aquatic life in the river, therefore the high total coliforms and *E. coli* contributed to the loss of macroinvertebrates at upstream and downstream of the Mokolo River, thus less species diversity was identified at the upstream, sand mining and downstream of the Mokolo River. The study by Wolmarans *et al.* (2014) indicated that high total coliforms and *E. coli* resulted in the loss of macroinvertebrates in the rivers.

Activities such as power station industries, human use, coal, recreational and coal mining within the catchment of the Mokolo River do not have negative impacts on the water quality of the Mokolo River, apart from sand mining and presence of faecal matter. However, these activities have negative impacts on the water quantity as they abstract water from the Mokolo River for their activities and processes. Sand mining activities are also blocking the water flow to the downstream area, which results in different water pools created and instream dams at the mining area.

The Mokolo River did not have water during the dry seasons because of high demand and supply on the system and physical disturbances due to sand mining. The reduction of water quantity in the Mokolo River has impacted negatively on the ecology of the system. When the river became dry, there was loss of macroinvertebrates, fish species, riparian vegetation, marginal vegetation and reduced recharge to the groundwater. There was a small variance in water quality of the Mokolo River throughout the years (2013 to 2018). In general, the water quality in the Mokolo River from 2013 to 2018 was not adversely affected and it is good except for turbidity, total coliforms and *E. coli* variables, as per the requirements of the TWQG standard limits.

High number of tolerant taxa to pollution was found at upstream (Tables 4.1 and 4.4), sand mining (Table 4.2 and 4.5) and downstream areas (Table 4.3 and 4.6). The ecological status of the Mokolo River at upstream and downstream areas was assessed to be class C fair (largely modified) in March 2018, however in November 2018 the river was assessed to be class B good (largely unmodified). The ecological status at the upstream and downstream areas in has improved from class C to Class B during the period of 2018.The Mokolo River was infested with reeds and marginal vegetation at upstream area (Fig. 4.15) and downstream area (Fig. 4.18) as there is no physical disturbances.

Fish species were also observed at the upstream and downstream during the assessment. Fish species could survive and breed at the upstream and downstream areas, as there is no sand mining and physical disturbances. At the sand mining area, the ecological status was assessed to be class E/F, which is unacceptable (seriously modified). Sand mining involves excavation, which results in instream sand stockpiles, river diversions, instream dams, disturbed riverbed, undercutting and collapsed riverbanks, removal of riparian and marginal vegetation, erosion, water ponds or pools created and high sedimentation load, which result in high turbidity, therefore sand mining has caused the loss of macroinvertebrates in the Mokolo River at the sand mining area.

Physical disturbances of erosion, undercutting and collapse of riverbanks, disturbed riverbed, loss of adjacent land and river deepened and widened, removal of riparian and marginal vegetation, instream sand stockpiles, instream dams, river diversions and water ponds or pools within the river (Figs. 4.20 to 4.27). The riverbed of the Mokolo River at the sand mining area is disturbed and, in the portions, which were mined there is no longer sand, however a muddy riverbed. The quality of the sand in the Mokolo River has changed as there is continuous sand mining and there is less sediment deposition due to minimum rainfall in the area and the river is not allowed to recover naturally.

According to Walker *et al.* (2018) the sand characteristics changes due to physical disturbances and erosion in a river and the sand will have poorly sorted sediments. The sand layer, which forms part of the riverbed in a river and not physical disturbed, will have well graded coarse sands. Therefore, in the Mokolo River due to over mining and continuous sand mining has resulted in the sand quality to change from well-graded coarse sand to poorly sorted sand. According to the study by Meng *et al.* (2018) indicates that physical disturbance of a riverbed changes the sediments quality in that system, which leads to less nutrient for macroinvertebrates to feed and survive. The riparian and marginal vegetation in a river serves a protection for the riverbanks and riverbed. Therefore, removal of riparian and marginal vegetation has negative impacts on the Mokolo River as the riverbanks and riverbed it is eroded and disturbed as there is no vegetation to protect the riverbanks and riverbed.

The ecological impacts determined in the Mokolo River of this study are change in water quality and reduced water quantity at upstream, sand mining and downstream of the Mokolo River. Ecological impacts determined at the sand mining area because of sand mining are; loss of riparian and marginal vegetation, reduced water quantity, disturbed riverbed, erosion, loss of adjacent land, undercutting and collapsed riverbanks, river deepened and widened, instream dams, instream sand stockpiles, and loss of macroinvertebrates. However, at the upstream and downstream of the Mokolo River there were no physical disturbance (no removal of riparian and marginal vegetation, no disturbed riverbed, no erosion and collapsing of riverbanks, however there was loss of macroinvertebrates due to change in water quality and water quantity.

The change in water quality was due to high turbidity, total coliforms and *E. coli* because of increased sedimentation load, erosion and presence of faecal matter in the system. The reduced water quantity in the river is because of increased abstraction from all the activities in the catchment and creation of instream dams, instream sand stockpiles and river diversions. Physical disturbances resulted in ecological impacts such as erosion, instream sand stockpiles, loss of adjacent land and removal of riparian and marginal vegetation, river deepened and widened, disturbed riverbed, undercutting and collapsed riverbanks, change in sand quality and water ponds or pools and river diversions at the sand mining areas as a result of sand mining. The ecological impacts on the Mokolo River are because of sand mining and have negatively influenced the ecology of the system.

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CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Lephalale area will be developed further in the future to be the economic hub for South Africa as it has largest coal reserves and supplying the power stations for electricity generation. It gives Lephalale area more opportunities to be developed further; however, as the area grows there will be high demand of sand for construction and water abstraction from the Mokolo River, which will have a significant negative impact on the ecosystem.

This study was based on three research questions. It was found that the change in water quality for certain quality parameters due to sand mining had impacted the ecology upstream and downstream of the Mokolo River. The physical disturbance and change in water quality, as a result of sand mining, have impacted macroinvertebrates, vegetation, riverbed and banks upstream and downstream of the Mokolo River. Sand mining resulted in a change of water quality, reduction of macroinvertebrates and physical disturbance of the Mokolo River during the period of this study, and no environmental mitigation measures were in place to minimise such impacts.

According to Seaman *et al*. (2013) sand miners and the Lephalale Farmers Association, in Lephalale area, indicated that sand mining in the Mokolo River has negative impacts on the water in the system. The flow of water in the river is altered; there are river diversions, riverbanks and riverbed disturbed, removal of riparian and marginal vegetation, which negatively influences the ecosystem of the Mokolo River (Seaman *et al.*, 2013).

The sand miners build weirs, instream dams and stockpiled sand within the river in order to keep the water away from the mining area. However, the weirs, dams and sand stockpiles create ponding of water and the downstream water users are negatively affected as they receive less water or no water for their human use and their farming activities. The sand in the Mokolo River acts as sponge which retains water and when the river is dry the water users can abstract water from the sand sponge, however since the sand miners remove sand from the river, there is no water that is trapped in the sand and the water users are negatively affected (Seaman *et al.,* 2013). The removal of sand from the Mokolo River disturbs the function of the sand sponge, which provides water to the water users during dry periods (Seaman *et al.,* 2013).

The aim of this study was to evaluate the ecological impacts associated with sand mining on the ecology, which includes the water quality, macroinvertebrates and physical characteristics of the Mokolo River. The study was also to assess the water quality variables that are associated with all the activities namely industries, wastewater treatment works, mining and agriculture that are within the catchment of the Mokolo River to determine whether they have negative impacts on the ecology of the river apart from sand mining. The study was also to help decision makers such as the Depts. of Water and Sanitation (DWS), of Environmental Affairs (DEA) and of Mineral Resources (DMR) to make objective decisions when granting authorisations for sand mining.

From the obtained results, the study identified that the water quality of the Mokolo River was assessed to have high turbidity, total coliforms and *Escherichia coli* (*E. coli*), which resulted in the loss of sensitive macroinvertebrates at the upstream and downstream areas. The study identified that the change in water quality in terms of turbidity at the upstream area was due to deposition of sediments during floods and rainy seasons, however at the downstream area it was identified that turbidity was high as result of sand mining. The study identified that the high turbidity occurred as a result of high sedimentation load from the sand mining area to the downstream area.

The high total coliforms and *E. coli* occurred because of disposal of domestic waste, disposal of dead animals by communities and faecal matter washed from the farming areas into the river, which increased the presence of bacteria at upstream and downstream areas in the Mokolo River. All the water quality variables monitored in the Mokolo River except turbidity, total coliforms and *E. coli* were not negatively affected by other activities such as industries, coal mining and recreational activities. However, the activities in the catchment rely on the Mokolo River for water supply, for their processes, and resulted in reduced water quantity in the system. The loss of macroinvertebrates in the Mokolo River is because of change in water quality and quantity.

The study identified that the change in water quality in terms of high turbidity, total coliforms and *E. coli* at the upstream and downstream areas is as result of sand mining and presence of faecal matter from farming areas and disposal of waste by the communities and has negative impacts on the ecology of the Mokolo River. According to Wolmarans *et al.* (2014), the loss of macroinvertebrates in the rivers occurs because of organic enrichment and physical disturbance. Therefore, the Mokolo River during the assessment period there was loss of macroinvertebrates as result of presence of faecal matter and high unstable sediments in the system caused by sand mining.

The study identified that at the study area in the Mokolo River at upstream, sand mining and downstream areas during the river health assessment there was limited species diversity and habitats. The study identified that the upstream and downstream areas in the Mokolo River the ecological status was classified as class C (fair), which improved to class B (good) during the study period. Limited taxa were found at the upstream and downstream areas; however, the areas were not adversely impacted as no physical disturbances were observed in the areas.

Sand mining does not have physical negative impacts on the riparian and marginal vegetation, riverbed and riverbanks at the upstream and downstream areas, as there is no sand mining and no physical disturbances of sand mining. The sand mining area ecological status was assessed to be classified as E/F (unacceptable). The study identified that very limited taxa was found at the sand mining area, which indicates that the area is negatively impacted due to excavation, removal of riparian and marginal vegetation, collapsing of riverbanks, erosion, disturbed riverbed, river diversions, blockage of water flow, creation of water ponds or pools and instream sand stockpiles. There was a loss of sensitive macroinvertebrates at the sand mining area because of physical disturbance.

The study identified the following ecological impacts: loss of sensitive macroinvertebrates, presence of number of tolerant taxa to pollution, less species diversity, erosion, change in water quality, reduced water quantity, loss of adjacent land, river diversions, river deepened and widened, instream sand stockpiles, undercutting and collapsed riverbanks, disturbed riverbed, water ponds or pools created, high sediments and removal of riparian and marginal vegetation at the sand mining area.

According to the study by Carel *et al.* (2018) sand and gravel mining in the water systems modifies the topography, change sand quality, increases turbidity, alters the flow, diversions created, removal of riparian and marginal vegetation which protects the riverbanks and riverbed and loss of aquatic species. The sand mining in a river continuously and over time affects the quality of sand (Sadeghi *et al.,* 2018). According to the study by the Sadeghi *et al.* (2018), indicates that the particle size distribution of sediments from the upstream to the downstream was affected. The study in the Mokolo River identified that during the sand mining there were no proper mitigation measures in place to prevent further deterioration and degradation of the aquatic ecosystem in the system.

Sand mining in the Mokolo River is frequently done without allowing the system to restore itself naturally and the river is mined continuously to provide sand for constructions in the area. The placement of sand stockpiles on the riverbed resulted in the loss of macroinvertebrates, loss of habitat for the aquatic species, reduced light penetration, and reduced production and feeding opportunities for other aquatic species at the sand mining area. The sand mining has changed the water quality (in terms of turbidity), influenced the physical characteristics and contributed to the loss of macroinvertebrates and aquatic species.

The analysis of this study indicates that due to sand mining in the Mokolo River there was change in water quality, water quantity, removal of riparian and marginal vegetation, river diversions, instream dams, instream sand stockpiles, loss of adjacent land, erosion, loss of sensitive macroinvertebrates and aquatic life, undercutting and collapsed riverbanks, disturbed riverbed, river deepened and widened ecological impacts. Therefore, sand mining has changed the aquatic ecosystem of the Mokolo River; hence it can be concluded that sand mining has negative impacts on the ecology of the Mokolo River.

5.2 Recommendations

Water is a scarce resource and requires proper usage, protection, conservation and management to ensure sustainability for the future. Therefore, before granting authorisations, the DWS, the DEA and the DMR must request detailed technical and scientific reports (e.g. Environmental Impact Assessment [EIA] for supporting the application of sand mining in the rivers in order to be granted with an authorisation. The technical and scientific reports must have detailed aspects of assessment of the present ecological status before mining, the environmental and ecological impacts that will arise from the sand mining activities and must provide detailed monitoring, management and rehabilitation plan.

The identified environmental and ecological impacts must have short, medium and long-term mitigation measures to ensure protection of the water resources. The sand mining must be done concurrent with the rehabilitation to ensure that the impacts are minimised as far as possible. Small-scale mining such as sand mining have accumulation of impacts which have long-term negative impacts on the water resources. Therefore, regulations aimed at small-scale mining such as sand mining within the water resources must be developed to ensure maximised protection of the aquatic ecosystems. Regulation and enforcement must be done more regularly on sand mining activities to ensure that the requirements in the authorisations are adhered to.

Public awareness should be done about legislations and regulations, which sand miners must comply with during sand mining and environmental monitoring and management of the ecological impacts, which will arise. According to the study by Meng *et al.* (2018) indicates that policy and regulations must be developed, to ensure that there is continuous management and monitoring of the environment and ecological impacts, which arise during sand mining.

During the sand mining, the riparian and marginal vegetation should not be removed as it serves as protection of the riverbanks and riverbed, and slows down the surface water run-off and flow of water in the system. The sand stockpiles must not be disposed on the riverbed as it changes the habitat, increases sedimentation load in the system, and there is loss of aquatic species. The sand mining must not occur beyond the undisturbed riverbed and below the surface water table as it functions as the recharge to the groundwater.

Sand mining must occur in phases and allow the previous mined areas to restore its sediments naturally in the system. Buffers must be created during the mining to ensure minimum disturbance to the river; however, the buffers must not divert and block the flow of water as it deprives the water users downstream and negatively impacts the aquatic ecosystem as relies on the water in the system. The sand mining must be limited to small portions in the river and screening of sand must occur at the disposal area, however not within the river in order to reduce turbidity and suspended solids in the system (Meng *et al.,* 2018). The undisturbed area next to the portion that is being mined must be protected to ensure that the aquatic species are not negatively impacted and by protecting the undisturbed area will ensure that aquatic species move to the portion that was mined to ensure restoration of aquatic species in that mined area (Meng *et al.,* 2018).

The vegetation on the land nearby rivers should not be cleared as it increases sediments into the river, as surface water run-off during rainy seasons is collected into the river. During excavation, mining must occur on the same level of sand layer and avoid digging holes in the rivers, which creates water pools or ponds. River diversions must not be created as it changes the natural morphology of the river and aquatic species will be lost. Blockage of the rivers with sand and creating of instream dams should not occur as it reduces the water flow in the system and deprives the downstream water users of water.

Environmental risk assessment must be done and it must include the different impacts, which will be associated with the mining, must assess the likelihood of those impacts and the extent of those impacts must be determined while considering the unlikelihood involved (Kaikkonen *et al.,* 2018). The ecological impacts in a water resource should be determined before the mining activity commences to ensure that mitigation measures are put in place and there is monitoring and management plans (Kaikkonen *et al.,* 2018).

Forio *et al.* (2017) indicates that stringent regulation and enforcement of sand mining is required in order to ensure that the rivers are restored. According to the study by Trop (2017) updated policy must be developed to ensure that it address all future sand mining activities and ensure monitoring and management of the impacts associated with the mining, in order to ensure sustainability of the water resources for the future. The regulators must ensure that the sand miners must conduct ecological impact assessment studies before mining commence and the studies should be part of the authorisation application in order to determine the magnitude of this sand mining activities on the water resources and grant authorisations with site specific requirements to ensure that the aquatic ecosystems are conserved and protected.

This study focused on the lower Mokolo River, where sand mining activities are taking place. It is therefore, recommended that future research on assessment of aquatic ecosystem must be conducted from where the Mokolo River starts and end and over a longer period in order to determine the ecological impacts of the whole system as result of accumulation of all direct and indirect sources of pollution and physical disturbances of activities throughout the system.

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APPENDICES

Appendix A: Turnitin digital receipt

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Mp Maeko
Assignment title:	DES 2019 Submissions
Submission title:	MSc Environmental Science disserta..
File name:	precious dissertation - to write pdf.d...
File size:	3.82M
Page count:	120
Word count:	28,010
Character count:	153,913
Submission date:	29-Oct-2019 07:48AM (UTC+0200)
Submission ID:	1202622335

UNISA

AN EVALUATION OF THE ECOLOGICAL IMPACTS OF SAND MINING ON THE MOKOLO RIVER IN LEPHALALE, SOUTH AFRICA

by

Mokgadi Precious Maeko

Submitted in accordance with the requirements
For the application in the Degree of

Masters of Environmental Science

in the
COLLEGE OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

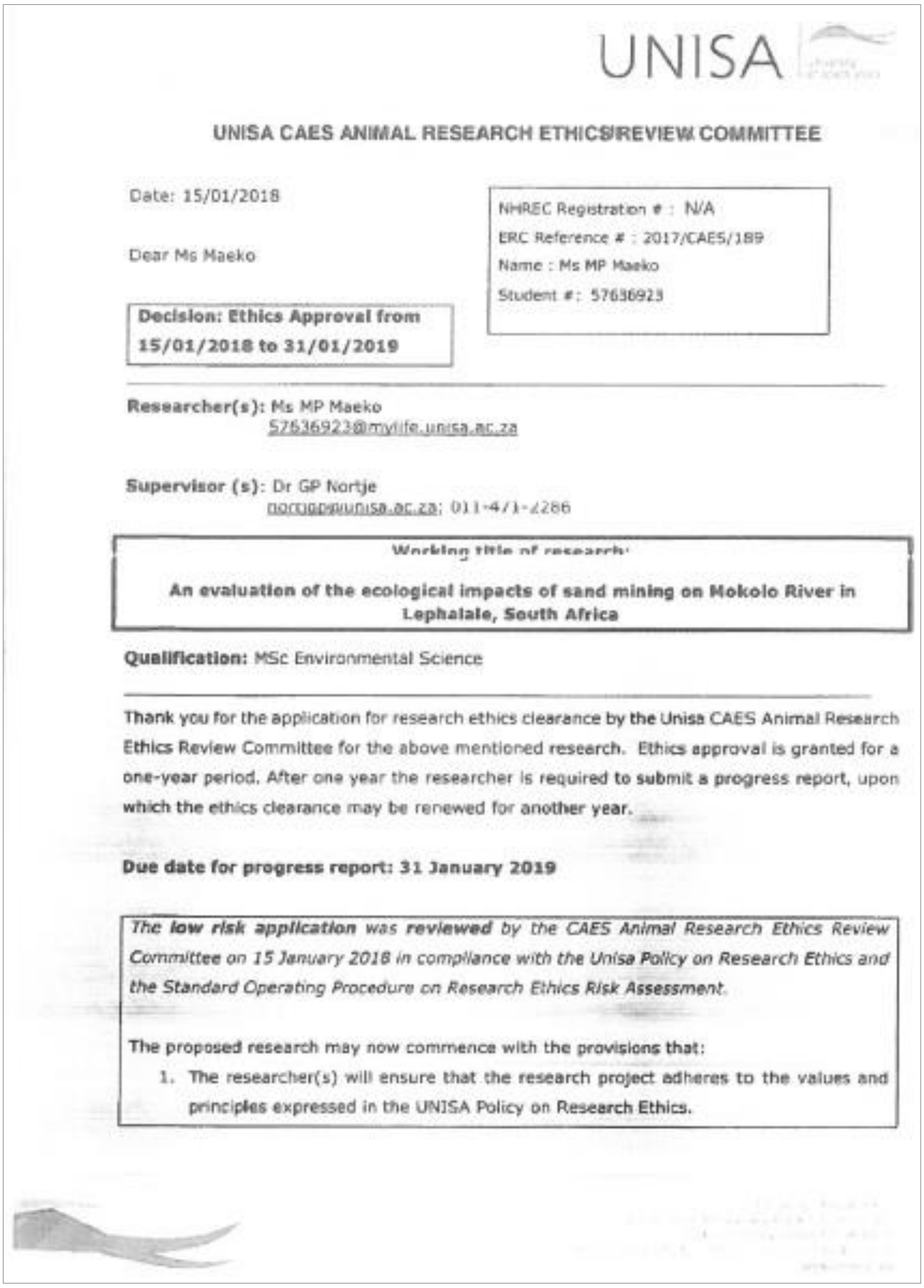
At the
UNIVERSITY OF SOUTH AFRICA

Supervisor:
Dr G.P. Nortjé

September 2019

Figure A.1: Turnitin digital receipt

Appendix B: Ethical clearance



UNISA

UNISA CAES ANIMAL RESEARCH ETHICS REVIEW COMMITTEE

Date: 15/01/2018

NHREC Registration # : N/A
ERC Reference # : 2017/CAES/189
Name : Ms MP Maeko
Student #: 57636923

Dear Ms Maeko

Decision: Ethics Approval from 15/01/2018 to 31/01/2019

Researcher(s): Ms MP Maeko
57636923@mylife.unisa.ac.za

Supervisor (s): Dr GP Nortje
nortjgp@unisa.ac.za; 011-471-2286

Working title of research:

An evaluation of the ecological impacts of sand mining on Mokolo River in Lephalale, South Africa

Qualification: MSc Environmental Science

Thank you for the application for research ethics clearance by the Unisa CAES Animal Research Ethics Review Committee for the above mentioned research. Ethics approval is granted for a one-year period. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

Due date for progress report: 31 January 2019

*The **low risk application** was **reviewed** by the CAES Animal Research Ethics Review Committee on 15 January 2018 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

Figure B.1a: Ethical clearance, first page

2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

*The reference number **2017/CAES/189** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Prof EL Kempen

Chair of CAES Animal Research ERC

E-mail: kempeel@unisa.ac.za

Tel: (011) 471-2241

Prof MJ Linington

Executive Dean : CAES

E-mail: lininmj@unisa.ac.za

Tel: (011) 471-3806

URERC 25.04.17 - Decision template (V2) - Approve

Figure B.1b: Ethical clearance, second page

UNISA university of south africa

CAES ANIMAL RESEARCH ETHICS COMMITTEE

Date: 31/01/2019

NHREC Registration # : N/A
REC Reference # : 2017/CAES/189
Name : Ms MP Maeko
Student #: 57636923

Dear Ms Maeko

Decision: Ethics Approval Renewal after First Review from 01/02/2019 to 31/01/2020

Researcher(s): Ms MP Maeko
57636923@mylife.unisa.ac.za

Supervisor (s): Dr GP Nortje
nortjgp@unisa.ac.za; 011-471-2286

Working title of research:

An evaluation of the ecological impacts of sand mining on Mokolo River in Lephalale, South Africa

Qualification: MSc Environmental Science

Thank you for the submission of your progress report to the CAES Animal Research Ethics Committee for the above mentioned research. Ethics approval is renewed for a one-year period. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

Due date for progress report: 31 January 2020

*The **low risk application** was **reviewed** by the CAES Animal Research Ethics Committee on 15 January 2018 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

Open Rubric

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Figure B.2a: Ethical clearance extension, first page

2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number ***2017/CAES/189*** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

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Figure B.2b: Ethical clearance extension, second page

Appendix C: Water quality results for the Mokolo River

Table C.1: Upstream results for the Mokolo River

Samples date	Variables	Units	TWQG Limits	Results
	pH	**(pH units)**	**6-8.5**	
25/11/2013 09:19				6.9
28/01/2014 11:28				7
25/02/2014 11:22				7.2
29/04/2014 12:23				7.3
15/05/2014 09:31				7.1
09/06/2014 13:27				7.5
07/07/2014 11:28				7.1
07/08/2014 10:30				7.3
03/09/2014 10:39				7.3
30/09/2014 09:32				7.5
28/10/2014 11:15				7.6
27/11/2014 10:52				7.7
18/02/2015 10:28				7.5
19/03/2015 11:01				7.8
13/04/2015 10:40				7.5
04/05/2015 11:33				7.6
01/06/2015 10:00				7.6
28/03/2018 10:47				7.1
24/04/2018 08:37				7.3
23/05/2018 08:57				7.4
23/11/2018 09:15				7.6
13/12/2018 09:45				7.4
	Electrical conductivity	**mS/m**	**0-40**	
25/11/2013 09:19				6
28/01/2014 11:28				5.8
25/02/2014 11:22				6
29/04/2014 12:23				5.1
15/05/2014 09:31				7
09/06/2014 13:27				5.7
07/07/2014 11:28				6.1
07/08/2014 10:30				6.3
03/09/2014 10:39				9.3
30/09/2014 09:32				6.9
28/10/2014 11:15				6.8

27/11/2014 10:52				6.9
18/02/2015 10:28				6.4
19/03/2015 11:01				6.4
13/04/2015 10:40				6.4
04/05/2015 11:33				6.4
01/06/2015 10:00				6.4
28/03/2018 10:47				7.7
24/04/2018 08:37				8.2
23/05/2018 08:57				9.6
23/11/2018 09:15				8.3
13/12/2018 09:45				19.9
	Turbidity	**NTU**	**0-1**	
25/11/2013 09:19				**38.7**
28/01/2014 11:28				**33.1**
25/02/2014 11:22				**7.16**
29/04/2014 12:23				**17.8**
15/05/2014 09:31				**12.6**
09/06/2014 13:27				**6.48**
07/07/2014 11:28				**6.03**
07/08/2014 10:30				**10.28**
03/09/2014 10:39				**3.9**
30/09/2014 09:32				**3.29**
28/10/2014 11:15				**6.8**
27/11/2014 10:52				**6.57**
18/02/2015 10:28				**4.58**
19/03/2015 11:01				**3.56**
13/04/2015 10:40				**4.19**
04/05/2015 11:33				**13.62**
01/06/2015 10:00				**3.01**
28/03/2018 10:47				**9.21**
24/04/2018 08:37				**2.52**
23/05/2018 08:57				**2.60**
23/11/2018 09:15				0.75
13/12/2018 09:45				0.93
	Fluoride	**(mg/l)**	**0-1**	
25/11/2013 09:19				0.05
28/01/2014 11:28				0.05
25/02/2014 11:22				0.05
29/04/2014 12:23				0.05
15/05/2014 09:31				0.05

09/06/2014 13:27				0.05
07/07/2014 11:28				0.05
07/08/2014 10:30				0.05
03/09/2014 10:39				0.05
30/09/2014 09:32				0.12
28/10/2014 11:15				0.05
27/11/2014 10:52				0.05
18/02/2015 10:28				0.05
19/03/2015 11:01				0.05
13/04/2015 10:40				0.05
04/05/2015 11:33				0.05
01/06/2015 10:00				0.05
28/03/2018 10:47				0.10
24/04/2018 08:37				0.10
23/05/2018 08:57				0.10
23/11/2018 09:15				0.10
13/12/2018 09:45				0.10
	Total alkalinity as $CaCO_3$	**(mg/l)**	**0-50**	
25/11/2013 09:19				18.8
28/01/2014 11:28				5.4
25/02/2014 11:22				18.8
29/04/2014 12:23				16.8
15/05/2014 09:31				25
09/06/2014 13:27				15.4
07/07/2014 11:28				18.6
07/08/2014 10:30				20.6
03/09/2014 10:39				16.6
30/09/2014 09:32				22.2
28/10/2014 11:15				19.4
27/11/2014 10:52				18.6
18/02/2015 10:28				20
19/03/2015 11:01				20.4
13/04/2015 10:40				22.9
04/05/2015 11:33				23.3
01/06/2015 10:00				23.3
28/03/2018 10:47				14.2
24/04/2018 08:37				18.8
23/05/2018 08:57				25.4
23/11/2018 09:15				27.1
13/12/2018 09:45				21.7

	Sodium (Na)	**(mg/l)**	**0-70**	
25/11/2013 09:19				5.34
28/01/2014 11:28				5.14
25/02/2014 11:22				5.62
29/04/2014 12:23				4.23
15/05/2014 09:31				2.76
09/06/2014 13:27				4.25
07/07/2014 11:28				4.87
07/08/2014 10:30				4.82
03/09/2014 10:39				8.69
30/09/2014 09:32				5.49
28/10/2014 11:15				5.85
27/11/2014 10:52				5.51
18/02/2015 10:28				5.42
19/03/2015 11:01				5.61
13/04/2015 10:40				5.27
04/05/2015 11:33				5.35
2015/06/01 10:00				5.42
28/03/2018 10:47				6.85
24/04/2018 08:37				7.66
23/05/2018 08:57				9.32
23/11/2018 09:15				6.93
13/12/2018 09:45				24.3
	Magnesium (Mg)	**(mg/l)**	**0-30**	
25/11/2013 09:19				2.09
28/01/2014 11:28				1.86
25/02/2014 11:22				2
29/04/2014 12:23				1.89
15/05/2014 09:31				2.76
09/06/2014 13:27				4.25
07/07/2014 11:28				2.06
07/08/2014 10:30				2.01
03/09/2014 10:39				2.49
30/09/2014 09:32				2.41
28/10/2014 11:15				2.41
27/11/2014 10:52				2.37
18/02/2015 10:28				2.12
19/03/2015 11:01				2.33
13/04/2015 10:40				2.25
04/05/2015 11:33				2.26
01/06/2015 10:00				2.32

28/03/2018 10:47				2.14
24/04/2018 08:37				2.17
23/05/2018 08:57				2.55
23/11/2018 09:15				4.57
13/12/2018 09:45				4.55
	Sulphate (SO_4)	**(mg/l)**	**0-200**	
25/11/2013 09:19				2.01
28/01/2014 11:28				4.91
25/02/2014 11:22				2.26
29/04/2014 12:23				4.34
15/05/2014 09:31				2.82
09/06/2014 13:27				3.06
07/07/2014 11:28				2.26
07/08/2014 10:30				2.69
03/09/2014 10:39				3.46
30/09/2014 09:32				2.92
28/10/2014 11:15				44.43
27/11/2014 10:52				3.91
18/02/2015 10:28				2.58
19/03/2015 11:01				3.69
13/04/2015 10:40				2.44
04/05/2015 11:33				3.87
01/06/2015 10:00				2.39
28/03/2018 10:47				8.11
24/04/2018 08:37				2.78
23/05/2018 08:57				2.99
23/11/2018 09:15				2.69
13/12/2018 09:45				9.02
	Chloride (Cl)	**(mg/l)**	**0-100**	
25/11/2013 09:19				4.9
28/01/2014 11:28				6.8
25/02/2014 11:22				5.9
29/04/2014 12:23				4.34
15/05/2014 09:31				5
09/06/2014 13:27				5.2
07/07/2014 11:28				6.2
07/08/2014 10:30				2.69
03/09/2014 10:39				14.9
30/09/2014 09:32				7.2
28/10/2014 11:15				6.7

27/11/2014 10:52			9.1
18/02/2015 10:28			6.9
19/03/2015 11:01			5.7
13/04/2015 10:40			6.4
04/05/2015 11:33			6
01/06/2015 10:00			6
28/03/2018 10:47			9.9
24/04/2018 08:37			11.2
23/05/2018 08:57			12.2
23/11/2018 09:15			8.4
13/12/2018 09:45			45.5
Potassium (K)	**(mg/l)**	**0-50**	
25/11/2013 09:19			1.13
28/01/2014 11:28			1.11
25/02/2014 11:22			1.39
29/04/2014 12:23			1.62
15/05/2014 09:31			0.78
09/06/2014 13:27			1.12
07/07/2014 11:28			1.17
07/08/2014 10:30			1
03/09/2014 10:39			1.11
30/09/2014 09:32			1.22
28/10/2014 11:15			1.26
27/11/2014 10:52			1.1
18/02/2015 10:28			0.93
19/03/2015 11:01			0.99
13/04/2015 10:40			0.92
04/05/2015 11:33			1.02
01/06/2015 10:00			0.92
28/03/2018 10:47			2.73
24/04/2018 08:37			1.20
23/05/2018 08:57			1.19
23/11/2018 09:15			1.19
13/12/2018 09:45			1.72
Calcium (Ca)	**(mg/l)**	**0-32**	
25/11/2013 09:19			3.48
28/01/2014 11:28			3.06
25/02/2014 11:22			3.32
29/04/2014 12:23			2.77
15/05/2014 09:31			4.61

09/06/2014 13:27				2.64
07/07/2014 11:28				3.31
07/08/2014 10:30				3.03
03/09/2014 10:39				3.8
30/09/2014 09:32				3.6
28/10/2014 11:15				3.61
27/11/2014 10:52				3.09
18/02/2015 10:28				2.81
19/03/2015 11:01				3.23
13/04/2015 10:40				3.17
04/05/2015 11:33				3.22
01/06/2015 10:00				3.22
28/03/2018 10:47				3.07
24/04/2018 08:37				3.34
23/05/2018 08:57				3.78
23/11/2018 09:15				4.57
13/12/2018 09:45				7.71
	Nitrate (NO_3-N)	**(mg/l)**	**0-6**	
25/11/2013 09:19				0.7
28/01/2014 11:28				0.7
25/02/2014 11:22				0.7
29/04/2014 12:23				0.7
15/05/2014 09:31				0.7
09/06/2014 13:27				0.7
07/07/2014 11:28				0.7
07/08/2014 10:30				0.7
03/09/2014 10:39				0.7
30/09/2014 09:32				0.7
28/10/2014 11:15				0.7
27/11/2014 10:52				0.7
18/02/2015 10:28				0.7
19/03/2015 11:01				0.7
13/04/2015 10:40				0.7
04/05/2015 11:33				0.7
01/06/2015 10:00				0.7
28/03/2018 10:47				0.06
24/04/2018 08:37				0.06
23/05/2018 08:57				0.06
23/11/2018 09:15				0.14
13/12/2018 09:45				0.6

	Total Coliforms	cfu/100ml	0-5	
25/11/2013 09:19				**866**
28/01/2014 11:28				**2 420**
25/02/2014 11:22				**2 420**
29/04/2014 12:23				**2 420**
15/05/2014 09:31				**2 420**
09/06/2014 13:27				**816**
07/07/2014 11:28				**2 420**
07/08/2014 10:30				**2 420**
03/09/2014 10:39				**1 733**
30/09/2014 09:32				**2 420**
28/10/2014 11:15				**2 420**
27/11/2014 10:52				**2 420**
18/02/2015 10:28				**2 420**
19/03/2015 11:01				**2 420**
13/04/2015 10:40				**2 420**
04/05/2015 11:33				**2 420**
01/06/2015 10:00				**1 414**
22/11/2016 07:06				**387**
28/03/2018 10:48				**2 420**
24/04/2018 08:35				**2 420**
23/05/2018 08:56				**1 553**
23/11/2018 09:15				**1 203**
13/12/2018 09:45				**2 420**
	E. coli	**cfu/100ml**	**0**	
25/11/2013 09:19				**22**
28/01/2014 11:28				**2 420**
25/02/2014 11:22				**93**
29/04/2014 12:23				**12**
15/05/2014 09:31				**1 733**
09/06/2014 13:27				**2**
07/07/2014 11:28				**18**
07/08/2014 10:30				**3**
03/09/2014 10:39				**5**
30/09/2014 09:32				**2**
28/10/2014 11:15				**0.5**
27/11/2014 10:52				**33**
18/02/2015 10:28				**20**
19/03/2015 11:01				**16**
13/04/2015 10:40				**42**

04/05/2015 11:33	**3**
01/06/2015 10:00	**10**
22/11/2016 07:06	**2**
28/03/2018 10:48	**138**
24/04/2018 08:35	**30**
23/05/2018 08:56	**40**
23/11/2018 09:15	**114**
13/12/2018 09:45	**727**

Table C.2: Downstream results for the Mokolo River

Samples date	Variables	Units	TWQG Limits	Results
	pH	**(pH units)**	**6-8.5**	
05/09/2013 12:14				6.8
29/10/2013 10:14				7.3
25/11/2013 13:00				6.9
18/12/2013 15:37				7.1
28/01/2014 10:12				6.8
25/02/2014 12:10				7.1
29/04/2014 10:02				7.4
12/05/2014 11:10				7.3
09/06/2014 09:39				7.4
07/07/2014 09:21				7.3
07/08/2014 11:53				7.7
03/09/2014 09:40				7.3
30/09/2014 10:25				7.5
28/10/2014 10:07				7.2
27/11/2014 11:59				7.3
20/01/2015 11:45				7.5
18/02/2015 11:58				7.6
19/03/2015 13:35				7.5
13/04/2015 12:42				7.5
04/05/2015 10:45				7.5
22/11/2016 10:14				7.59
19/12/2016 09:00				7.46
28/03/2018 12:43				7.2
24/04/2018 09:04				7.4
23/05/2018 09:17				7.0
23/11/2018 11:31				7.7
13/12/2018 10:00				7.3

	Electrical conductivity	mS/m	0-40	
05/09/2013 12:14				15.3
29/10/2013 10:14				11.8
25/11/2013 13:00				14
18/12/2013 15:37				8.3
28/01/2014 10:12				5.9
25/02/2014 12:10				7.3
29/04/2014 10:02				6.9
12/05/2014 11:10				6.8
09/06/2014 09:39				7.5
07/07/2014 09:21				7.9
07/08/2014 11:53				8.1
03/09/2014 09:40				11.3
30/09/2014 10:25				8
28/10/2014 10:07				39.5
27/11/2014 11:59				10.4
20/01/2015 11:45				7.2
18/02/2015 11:58				6.9
19/03/2015 13:35				8.1
13/04/2015 12:42				7.2
04/05/2015 10:45				8
22/11/2016 10:14				16.84
19/12/2016 09:00				14.05
28/03/2018 12:43				8.2
24/04/2018 09:04				10.2
23/05/2018 09:17				19.2
23/11/2018 11:31				9
13/12/2018 10:00				8.8
	Turbidity	**NTU**	**0-1**	
05/09/2013 12:14				**12.34**
29/10/2013 10:14				**4.86**
25/11/2013 13:00				**6.4**
18/12/2013 15:37				**6.19**
28/01/2014 10:12				**3.48**
25/02/2014 12:10				**8.76**
29/04/2014 10:02				**21.5**
12/05/2014 11:10				**18.4**
09/06/2014 09:39				**9.41**
07/07/2014 09:21				**7.83**
07/08/2014 11:53				**5.15**

03/09/2014 09:40			**3.35**
30/09/2014 10:25			**2.68**
28/10/2014 10:07			**4.67**
27/11/2014 11:59			**1.77**
20/01/2015 11:45			**5.29**
18/02/2015 11:58			**9.74**
19/03/2015 13:35			**0.5**
13/04/2015 12:42			**2.5**
04/05/2015 10:45			**2.42**
22/11/2016 10:14			**8.34**
19/12/2016 09:00			**0.85**
28/03/2018 12:43			**35.80**
24/04/2018 09:04			**2.38**
23/05/2018 09:17			**1.51**
23/11/2018 11:31			**1.69**
13/12/2018 10:00			0.37
Fluoride	**(mg/l)**	**0-1.0**	
05/09/2013 12:14			0.05
29/10/2013 10:14			0.05
25/11/2013 13:00			0.05
18/12/2013 15:37			0.14
28/01/2014 10:12			0.05
25/02/2014 12:10			0.05
29/04/2014 10:02			0.05
12/05/2014 11:10			0.05
09/06/2014 09:39			0.05
07/07/2014 09:21			0.05
07/08/2014 11:53			0.05
03/09/2014 09:40			0.05
30/09/2014 10:25			0.05
28/10/2014 10:07			0.05
27/11/2014 11:59			0.05
20/01/2015 11:45			0.05
18/02/2015 11:58			0.05
19/03/2015 13:35			0.05
13/04/2015 12:42			0.11
04/05/2015 10:45			0.05
22/11/2016 10:14			0.16
19/12/2016 09:00			0.035
28/03/2018 12:43			0.10
24/04/2018 09:04			0.10
23/05/2018 09:17			0.10

23/11/2018 11:31				0.10
13/12/2018 10:00				0.10
	Total alkalinity as $CaCO_3$	**(mg/l)**	**0-50**	
25/11/2013 13:00				24.6
18/12/2013 15:37				14.8
28/01/2014 10:12				9
25/02/2014 12:10				13.8
29/04/2014 10:02				17.6
12/05/2014 11:10				16.2
09/06/2014 09:39				16.6
07/07/2014 09:21				19.2
07/08/2014 11:53				20.2
03/09/2014 09:40				17.8
30/09/2014 10:25				18.6
28/10/2014 10:07				48.4
27/11/2014 11:59				18.2
20/01/2015 11:45				17.8
18/02/2015 11:58				22.4
19/03/2015 13:35				20.6
13/04/2015 12:42				20.4
04/05/2015 10:45				24.2
22/11/2016 10:14				6
19/12/2016 09:00				6
28/03/2018 12:43				15.8
24/04/2018 09:04				19.6
23/05/2018 09:17				23.8
23/11/2018 11:31				26.7
13/12/2018 10:00				20.8
	Sodium (Na)	**(mg/l)**	**0-70**	
05/09/2013 12:14				15.88
29/10/2013 10:14				11.39
25/11/2013 13:00				13.3
18/12/2013 15:37				10.32
28/01/2014 10:12				6.4
25/02/2014 12:10				7.99
29/04/2014 10:02				6.66
12/05/2014 11:10				6.03
09/06/2014 09:39				6.64
07/07/2014 09:21				7.16
07/08/2014 11:53				7.13

03/09/2014 09:40			10.43
30/09/2014 10:25			7.41
28/10/2014 10:07			43.36
27/11/2014 11:59			11.78
20/01/2015 11:45			6.98
18/02/2015 11:58			5.97
19/03/2015 13:35			7.61
13/04/2015 12:42			6.43
04/05/2015 10:45			7.32
22/11/2016 10:14			6.77
19/12/2016 09:00			12.69
28/03/2018 12:43			7.16
24/04/2018 09:04			9.42
23/05/2018 09:17			21.01
23/11/2018 11:31			8.02
13/12/2018 10:00			8.07
Magnesium (Mg)	**(mg/l)**	**0-30**	
05/09/2013 12:14			3.9
29/10/2013 10:14			3.18
25/11/2013 13:00			4.1
18/12/2013 15:37			2.8
28/01/2014 10:12			1.46
25/02/2014 12:10			1.95
29/04/2014 10:02			2.34
12/05/2014 11:10			2.15
09/06/2014 09:39			2.21
07/07/2014 09:21			2.21
07/08/2014 11:53			2.15
03/09/2014 09:40			3.07
30/09/2014 10:25			2.43
28/10/2014 10:07			9.62
27/11/2014 11:59			3.13
20/01/2015 11:45			2.56
18/02/2015 11:58			2.32
19/03/2015 13:35			2.63
13/04/2015 12:42			2.2
04/05/2015 10:45			2.57
22/11/2016 10:14			1.26
19/12/2016 09:00			3.08
28/03/2018 12:43			2.17
24/04/2018 09:04			2.43
23/05/2018 09:17			4.06

23/11/2018 11:31				3.03
13/12/2018 10:00				2.6
	Sulphate (SO_4)	**(mg/l)**	**0-200**	
05/09/2013 12:14				6.95
29/10/2013 10:14				4.16
25/11/2013 13:00				4.1
18/12/2013 15:37				8.64
28/01/2014 10:12				2.3
25/02/2014 12:10				2.56
29/04/2014 10:02				3.52
12/05/2014 11:10				4.36
09/06/2014 09:39				2.98
07/07/2014 09:21				2.7
07/08/2014 11:53				3.38
03/09/2014 09:40				3.96
30/09/2014 10:25				5.43
28/10/2014 10:07				14.49
27/11/2014 11:59				5
20/01/2015 11:45				4.55
18/02/2015 11:58				2.34
19/03/2015 13:35				3.62
13/04/2015 12:42				3
04/05/2015 10:45				5.18
22/11/2016 10:14				3.77
19/12/2016 09:00				1.65
28/03/2018 12:43				1.47
24/04/2018 09:04				4
23/05/2018 09:17				7.93
23/11/2018 11:31				2.5
13/12/2018 10:00				3.43
	Chloride (Cl)	**(mg/l)**	**0-100**	
05/09/2013 12:14				29.6
29/10/2013 10:14				22.8
25/11/2013 13:00				26.5
18/12/2013 15:37				12.4
28/01/2014 10:12				9.7
25/02/2014 12:10				13.7
29/04/2014 10:02				9.6
12/05/2014 11:10				9.8
09/06/2014 09:39				11

07/07/2014 09:21			13
07/08/2014 11:53			12
03/09/2014 09:40			19.8
30/09/2014 10:25			10.9
28/10/2014 10:07			86.4
27/11/2014 11:59			19
20/01/2015 11:45			8.1
18/02/2015 11:58			7.4
19/03/2015 13:35			10.2
13/04/2015 12:42			10.4
04/05/2015 10:45			10
22/11/2016 10:14			27.74
19/12/2016 09:00			16.52
28/03/2018 12:43			10.5
24/04/2018 09:04			15.5
23/05/2018 09:17			39.4
23/11/2018 11:31			10.3
13/12/2018 10:00			12
Potassium (K)	**(mg/l)**	**0-50**	
05/09/2013 12:14			0.94
29/10/2013 10:14			1.18
25/11/2013 13:00			1.12
18/12/2013 15:37			3
28/01/2014 10:12			0.91
25/02/2014 12:10			0.67
29/04/2014 10:02			1.61
12/05/2014 11:10			1.33
09/06/2014 09:39			1.12
07/07/2014 09:21			1.07
07/08/2014 11:53			0.96
03/09/2014 09:40			1.12
30/09/2014 10:25			1.1
28/10/2014 10:07			2.32
27/11/2014 11:59			1.75
20/01/2015 11:45			1.16
18/02/2015 11:58			0.99
19/03/2015 13:35			1.07
13/04/2015 12:42			0.89
04/05/2015 10:45			1.01
22/11/2016 10:14			0.5

19/12/2016 09:00			1.55
28/03/2018 12:43			3
24/04/2018 09:04			1.29
23/05/2018 09:17			1.39
23/11/2018 11:31			1.25
13/12/2018 10:00			2.02
Calcium (Ca)	**(mg/l)**	**0-32**	
05/09/2013 12:14			6.81
29/10/2013 10:14			5.12
25/11/2013 13:00			6.71
18/12/2013 15:37			4.45
28/01/2014 10:12			2.25
25/02/2014 12:10			3.13
29/04/2014 10:02			3.51
12/05/2014 11:10			3.11
09/06/2014 09:39			3.23
07/07/2014 09:21			3.57
07/08/2014 11:53			3.3
03/09/2014 09:40			4.64
30/09/2014 10:25			3.56
28/10/2014 10:07			15.72
27/11/2014 11:59			3.54
20/01/2015 11:45			3.47
18/02/2015 11:58			3.23
19/03/2015 13:35			3.71
13/04/2015 12:42			3
04/05/2015 10:45			3.7
28/03/2018 12:43			3.68
24/04/2018 09:04			4.03
23/05/2018 09:17			7.24
23/11/2018 11:31			4.75
13/12/2018 10:00			4.02
Nitrate (NO_3-N)	**(mg/l)**	**0-6**	
05/09/2013 12:14			2.2
29/10/2013 10:14			0.7
25/11/2013 13:00			0.7
18/12/2013 15:37			0.7
28/01/2014 10:12			0.7
25/02/2014 12:10			0.7
29/04/2014 10:02			0.7

12/05/2014 11:10			0.7
09/06/2014 09:39			0.7
07/07/2014 09:21			0.7
07/08/2014 11:53			0.7
03/09/2014 09:40			0.7
30/09/2014 10:25			0.7
28/10/2014 10:07			0.7
27/11/2014 11:59			0.7
20/01/2015 11:45			0.7
18/02/2015 11:58			0.7
19/03/2015 13:35			0.7
13/04/2015 12:42			0.7
04/05/2015 10:45			0.7
22/11/2016 10:14			2.85
19/12/2016 09:00			0.27
28/03/2018 12:43			0.06
24/04/2018 09:04			0.06
23/05/2018 09:17			0.06
23/11/2018 11:31			0.06
13/12/2018 10:00			0.06
Total coliforms	**cfu/100ml**	**0-5**	
29/10/2013 10:14			**2 420**
25/11/2013 13:00			**2 420**
18/12/2013 15:37			**2 420**
28/01/2014 10:12			**2 420**
25/02/2014 12:10			**2 420**
29/04/2014 10:02			**2 420**
12/05/2014 11:10			**2 420**
09/06/2014 09:39			**1 733**
07/08/2014 11:53			**2 420**
03/09/2014 09:40			**2 420**
30/09/2014 10:25			**2 420**
28/10/2014 10:07			**2 420**
27/11/2014 11:59			**2 420**
20/01/2015 11:45			**2 420**
18/02/2015 11:58			**2 420**
13/04/2015 12:42			**1 300**
28/03/2018 12:44			**2 420**
24/04/2018 08:35			**2 420**
23/05/2018 09:16			**2 420**
23/11/2018 11:31			**2 420**
13/12/2018 10:00			**2 420**

	E. coli	cfu/100ml	0	
29/10/2013 10:14				**1 120**
25/11/2013 13:00				**105**
18/12/2013 15:37				**36**
28/01/2014 10:12				**345**
25/02/2014 12:10				**238**
29/04/2014 10:02				**36**
12/05/2014 11:10				**41**
09/06/2014 09:39				**14**
07/08/2014 11:53				**131**
03/09/2014 09:40				**22**
30/09/2014 10:25				**64**
28/10/2014 10:07				**816**
27/11/2014 11:59				**99**
20/01/2015 11:45				**86**
18/02/2015 11:58				**70**
13/04/2015 12:42				**50**
28/03/2018 12:44				**387**
24/04/2018 08:35				**96**
23/05/2018 09:16				**613**
23/11/2018 11:31				**248**
13/12/2018 10:00				**1 203**

Appendix D: SASS5 results for the Mokolo River

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd-mm-yr):	28-Mar-18		(dd.ddddd)
Site Code:	Upstream Area	Grid reference (dd mm ss.s) Lat: S	
Collector/Sampler:	Mokgadi and Avron	Long: E	
River:	Mokolo River	Datum (WGS84/Cape):	
Level 1 Ecoregion:	Limpopo plain	Altitude (m):	
Quaternary Catchment:	A42C-A42J	Zonation:	

Site Description:	Temp (°C):		Project	Flow:	Low
Marginal vegetation observed	pH:		Project Name: MSC STUDY	Clarity (cm):	
	DO (mg/L):		AN EVALUATION OF THE ECOLOGICAL IMPACTS OF SAND MINING ON MOKOLO RIVER	Turbidity:	V Low
	Cond (mS/m):			Colour:	Normal transparent
	Riparian Disturbance:	No disturbance			
	Instream Disturbance:	Abstraction of water by farmers			

Biotopes Sampled (tick & rate)	Rating (1 - 5)	Time (min)
Stones In Current (SIC)	0	09:15
Stones Out Of Current (SOOC)	0	
Bedrock	0	
Aquatic Veg	0	
MargVeg In Current	2	
MargVeg Out Of Current	3	
Gravel	2	
Sand	5	
Mud	0	
Hand picking/Visual observation	2	
Biotope Score (%)		

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6		A	A	A
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6		A	B	B
Libellulidae (Darters/Skimmers)	4		1		1
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3			1	1
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5			1	1
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8			A	A
Hydrophilidae* (Water scavenger beetles)	5		1		1
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5			1	1
Chironomidae (Midges)	2				
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3		A		A
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					45
No. of Taxa					9
ASPT					5.0

Other biota:
Fish x 2

Comments/Observations:
Limited species diversity in the area.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Figure D.1a: SASS5 results for upstream for the Mokolo River, first page

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd-mm-yr):	23-Nov-18			(dd.ddddd)	
Site Code:	Upstream Area	Grid reference (dd mm ss.s) Lat:	S		
Collector/Sampler:	Mokgadi and Avron	Long:	E		
River:	Mokolo River	Datum (WGS84/Cape):			
Level 1 Ecoregion:	Limpopo Plain	Altitude (m):			
Quaternary Catchment:	A42C-A42J	Zonation:			

Site Description:	Temp (°C):		Project	Flow:	Low
Marginal vegetation observed	pH:		Project Name: MSC STUDY	Clarity (cm):	
	DO (mg/L):		AN EVALUATION OF THE ECOLOGICAL IMPACTS OF SAND MINING ON MOKOLO RIVER	Turbidity:	V Low
	Cond (mS/m):			Colour:	Normal Transparent
	Riparian Disturbance:	No disturbance			
	Instream Disturbance:	Abstraction of water by farmers			

Biotopes Sampled (tick & rate)	Rating (1 - 5)	Time (min)
Stones In Current (SIC)	0	09:14
Stones Out Of Current (SOOC)	0	
Bedrock	0	
Aquatic Veg	0	
MargVeg In Current	2	
MargVeg Out Of Current	3	
Gravel	2	
Sand	5	
Mud	0	
Hand picking/Visual observation	4	
Biotope Score (%)		

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6		A	A	A
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6		A	A	A
Libellulidae (Darters/Skimmers)	4		A		A
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3			A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7		1		1
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12		1		1
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5			A	A
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2				
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6		1		1
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3		A	A	A
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					52
No. of Taxa					9
ASPT					5.7

Other biota:

Fish x 4

Comments/Observations:

Limited species diversity in the area.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Figure D.1b: SASS5 results for upstream for the Mokolo River, second page

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd-mm-yr):	28-Mar-18		(dd.ddddd)	Biotopes Sampled (tick & rate)	Rating (1 - 5) / Time (min)
Site Code:	Sand Mining Area	Grid reference (dd mm ss.s) Lat: S		Stones In Current (SIC)	0 / 11:20
Collector/Sampler:	Mokgadi and Avron	Long: E		Stones Out Of Current (SOOC)	0
River:	Mokolo River	Datum (WGS84/Cape):		Bedrock	0
Level 1 Ecoregion:	Limpopo plain	Altitude (m):		Aquatic Veg	0
Quaternary Catchment:	A42C-A42J	Zonation:		MargVeg In Current	1
	Temp (°C):	Project	Flow: Medium	MargVeg Out Of Current	1
Site Description:	pH:	Project Name: MSC STUDY	Clarity (cm):	Gravel	0
Sand stockpiles within the river. River diversions. Blockage of flow of water. Water pools, erosion, no marginal vegetation at the mined portions and disturbed riverbed and riverbanks.	DO (mg/L):	AN EVALUATION OF THE ECOLOGICAL IMPACTS OF SAND MINING ON MOKOLO RIVER	Turbidity: High	Sand	3
	Cond (mS/m):		Colour: Tea Brown	Mud	2
	Riparian Disturbance:	Erosion and removal of raparian vegetation on the riverbanks.		Hand picking/Visual observation	0
	Instream Disturbance:	Disturbed riverbed and Sand stockpiles within the river. River diversions.		Biotope Score (%)	

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6		A	A	A
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6		1	A	A
Libellulidae (Darters/Skimmers)	4		1		1
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		1		1
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		1		1
Chironomidae (Midges)	2		A	A	A
Culicidae* (Mosquitoes)	1		1		1
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		A		A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3		1		1
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					37
No. of Taxa					9
ASPT					4.11

Other biota:
NONE

Comments/Observations:
Limited species diversity in the area.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Figure D.2a: SASS5 results for sand mining for the Mokolo River, first page

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd-mm-yr):	23-Nov-18		(dd.ddddd)	**Biotopes Sampled (tick & rate)**	Rating (1 - 5) / Time (min)
Site Code:	Sand Mining Area	Grid reference (dd mm ss.s) Lat: S		Stones In Current (SIC)	0 / 10:35
Collector/Sampler:	Mokgadi and Avron	Long: E		Stones Out Of Current (SOOC)	0
River:	Mokolo River	Datum (WGS84/Cape):		Bedrock	0
Level 1 Ecoregion:	Limpopo plain	Altitude (m):		Aquatic Veg	0
Quaternary Catchment:	A42C-A42J	Zonation:		MargVeg In Current	1
	Temp (°C):	**Project**	Flow: Low	MargVeg Out Of Current	1
Site Description:	pH:	Project Name: MSC STUDY	Clarity (cm):	Gravel	0
Sand stockpiles within the river. River diversions. Blockage of flow of water. Water pools, erosion, no marginal vegetation at the mined portions and disturbed riverbed and riverbanks.	DO (mg/L):	AN EVALUATION OF THE ECOLOGICAL IMPACTS OF SAND MINING ON MOKOLO RIVER	Turbidity: High	Sand	3
	Cond (mS/m):		Colour: Tea Brown	Mud	2
	Riparian Disturbance:	Erosion and removal of raparian vegetation on the riverbanks.		Hand picking/Visual observation	0
	Instream Disturbance:	Disturbed riverbed and Sand stockpiles within the river. River diversions.		Biotope Score (%)	

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6		A	A	A
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4		A	A	A
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5		A	A	A
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		1		1
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		1		1
Chironomidae (Midges)	2		A	A	A
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		1	1	1
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					32
No. of Taxa					7
ASPT					4.5

Other biota:
NONE

Comments/Observations:
Limited species diversity in the area.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Figure D.2b: SASS5 results for sand mining for the Mokolo River, second page

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd-mm-yr):	28-Mar-18
Site Code:	Downstream Area
Collector/Sampler:	Mokgadi and Avron
River:	Mokolo River
Level 1 Ecoregion:	Limpopo plain
Quaternary Catchment:	A42C-A42J
Site Description:	Marginal vegetation observed. There is mud and gravel in the area.

Grid reference (dd mm ss.s)			(dd.ddddd)
Lat:	S		
Long:	E		
Datum (WGS84/Cape):			
Altitude (m):			
Zonation:			

Temp (°C):	
pH:	
DO (mg/L):	
Cond (mS/m):	
Riparian Disturbance:	No disturbance
Instream Disturbance:	Road crossing bridge instream and abstraction of water by farmers

Project	
Project Name: MSC STUDY	
AN EVALUATION OF THE ECOLOGICAL IMPACTS OF SAND MINING ON MOKOLO RIVER	
Flow:	Low
Clarity (cm):	
Turbidity:	V Low
Colour:	Light Green

Biotopes Sampled (tick & rate)	Rating (1 - 5)	Time (min)
Stones In Current (SIC)	0	12:42
Stones Out Of Current (SOOC)	0	
Bedrock	0	
Aquatic Veg	0	
MargVeg In Current	2	
MargVeg Out Of Current	3	
Gravel	2	
Sand	2	
Mud	2	
Hand picking/Visual observation	1	
Biotope Score (%)		

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12		B		B
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6			1	1
Libellulidae (Darters/Skimmers)	4			1	1
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		1		1
Corixidae* (Water boatmen)	3		A	A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3		A		A
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5			1	1
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12		1		1
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5		1		1
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2		1	1	1
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6		1		1
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					61
No. of Taxa					11
ASPT					5.54

Other biota:
Fish X 1

Comments/Observations:
Limited diversity in the area.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m^2. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Figure D.3a: SASS5 results for downstream for the Mokolo River, first page

SASS Version 5 Score Sheet

Version date: Sep 2005

Date (dd-mm-yr):	23-Nov-18				(dd.ddddd)
Site Code:	Downstream Area	**Grid reference (dd mm ss.s) Lat:**	S		
Collector/Sampler:	Mokgadi and Avron	**Long:**	E		
River:	Mokolo River	**Datum (WGS84/Cape):**			
Level 1 Ecoregion:	Limpopo plain	**Altitude (m):**			
Quaternary Catchment:	A42C-A42J	**Zonation:**			

	Temp (°C):		**Project**	Flow:	Low
Site Description:	pH:		Project Name: MSC STUDY	Clarity (cm):	
Marginal vegetation observed. There is mud and gravel in the area.	DO (mg/L):		AN EVALUATION OF THE ECOLOGICAL IMPACTS OF SAND MINING ON MOKOLO RIVER	Turbidity:	V Low
	Cond (mS/m):			Colour:	Light Green
	Riparian Disturbance:	No disturbance			
	Instream Disturbance:	Road crossing bridge instream and abstraction of water by farmers			

Biotopes Sampled (tick & rate)	Rating (1 - 5)	Time (min)
Stones In Current (SIC)	0	11:56
Stones Out Of Current (SOOC)	0	
Bedrock	0	
Aquatic Veg	0	
MargVeg In Current	2	
MargVeg Out Of Current	3	
Gravel	2	
Sand	2	
Mud	2	
Hand picking/Visual observation	6	
Biotope Score (%)		

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8		1		1
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12		B	B	B
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6		A	A	A
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3		A	A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3		A	A	A
Notonectidae* (Backswimmers)	3		A	A	A
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5			1	1
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5		1	1	1
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12		1		1
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5		A	1	A
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2		1	1	1
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					64
No. of Taxa					11
ASPT					5.8

Other biota:
Fish X 6

Comments/Observations:
Limited diversity in the area.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
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Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Figure D.3b: SASS5 results for downstream for the Mokolo River, second page